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The Reshaping of China's Industry Chains

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Acknowledgments

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Chapter 1
Scale Matters: Industry Chain Restructuring Amid Deglobalization

Abstract Since the outbreak of COVID-19, the global supply chain has been disrupted by three rounds of shocks. During the explosive spread of the pandemic in 2020, the halt in economic activity eroded production and inventory, while quarantine measures undermined employment. When global demand rebounded in 2021, the demand–supply imbalance deteriorated due to low inventory, weak production, as well as disruptions to transportation and logistics. In addition, the outbreak of the Russia-Ukraine conflict in 2022 also had major impacts on the supply of energy, raw materials, and food. These shocks to global industry chains and supply chains have exacerbated impacts of the pandemic and geopolitical conflicts on the world economy, prompting the public and private sectors to reexamine stability of supply. At the micro level, business entities are attaching greater importance to the stability of supply chains. At the macro level, governments stress industry chain resilience and view industry competitiveness from both efficiency and security perspectives.

The *Report to the 20th CPC National Congress* states that: "Pursuing high-quality development as our overarching task, we will make sure that our implementation of the strategy to expand domestic demand is integrated with our efforts to deepen supply-side structural reform; we will boost the dynamism and reliability of the domestic economy while engaging at a higher level in the global economy; and we will move faster to build a modernized economy. We will raise total factor productivity, and make China's industrial and supply chains more resilient and secure". While China plays a key role in global industry chains after four decades of reform and opening-up with rapid economic growth, the country is confronted with new challenges as high-quality development calls for attention to both efficiency and security of industry chains.

The CICC Research Department and CICC Global Institute collaborated to publish *The Reshaping of China's Industry Chains,* an in-depth report that provides a comprehensive analysis on opportunities and challenges for industry chain development in a multitude of aspects, including the macro economy, various sectors, technologies, policies, as well as domestic and international issues from both efficiency and security perspectives. In particular, the report suggests that China should take full advantage of its economies of scale to improve both efficiency and security

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of industry chains. In this preface, we provide readers with some of our thoughts about the future of global supply chains from a macro perspective.

Keywords Industry chain · Deglobalization · Spatial economy · Efficiency · Security · Economies of scale

1.1 Deglobalization: History Has Not Come to an End

Economics' greatest contribution to human society is probably its advocacy of free trade. Before Adam Smith published *The Wealth of Nations*, most people believed that wealth accumulation is equivalent to the possession of gold, and that resource allocation is accomplished by conquering land and colonies with brute force. However, Smith revealed that wealth can be created through labor specialization and trade in free markets, which are defined as markets not controlled by rent seekers such as monarchs, aristocrats, and landlords. Despite some controversies about the results of free trade—such as the contention that there are both winners and losers in free trade, and that protection of emerging industries and innovative sectors is conducive to economic growth—most economists tend to support free trade.

Neoclassical economics, which has been the dominant school of economic thought over the past four decades, has led to government policies that promote market economies and financial liberalization around the world. This has resulted in substantial growth of global trade in both goods and services and cross-border flows of capital, technologies, and information. As technological progress has lowered the cost of transportation and information exchange, the division of labor has become increasingly specialized, and global industry chains have served as a key engine for efficiency enhancement and economic development. Francis Fukuyama, an American political scientist, argued in 1989 that humanity is at "the end of history … that is, the end point of mankind's ideological evolution[1]", and that history has evolved towards a single final destination: Some form of liberal democracy and a market economy. Fukuyama believes that market economies would gradually form a unified community of learning and culture since "economic forces … are now encouraging the breakdown of national barriers through the creation of a single, integrated world market".[2] In addition, Fukuyama claims that "Within the post-historical world, the chief axis of interaction between states would be economic…"[3] rather than political.

However, trade protectionism has been on the rise since the global financial crisis in 2008. Moreover, drivers of deglobalization have expanded from economic factors to non-economic ones since the outbreak of COVID-19 and the Russia-Ukraine conflict. While the pandemic had tremendous short-term impacts on supply chains,

[1] Fukuyama, Francis. "The End of History?" *The National Interest*, no. 16, 1989, pp. 3–18.

[2] Fukuyama, Francis. *The End of History and the Last Man.* Free Press, 1992.

[3] Fukuyama, Francis. *The End of History and the Last Man.* Free Press, 1992.

more and more signs indicate that geopolitics has again become a more fundamental factor behind global resource allocation. Considerations about national security have made it necessary to mitigate the risk of abusing industry chains as a tool for geopolitical rivalry. Therefore, history has not come to an end in the age of deglobalization.

Although COVID-19 has inflicted major impacts on global supply chains, it has also revealed international trade's contribution to pandemic responses around the world. On the one hand, the production of certain goods in some countries may be negatively affected by pandemic-caused hurdles to imports of intermediate goods. On the other hand, the disrupted domestic supply of such goods could be substituted with imports from other countries less affected by the pandemic at the moment. Although supply chains of many companies have been substantially impacted by the pandemic at the micro level, global industry chains have remained resilient during the pandemic from a macro perspective. For example, China's exports have played a key role in fulfilling demand in other countries. In fact, China's share of international trade in GDP has increased since the outbreak of COVID-19.

Geopolitical rivalry has more profound and far-reaching effects on the evolution of global industry chains. Moreover, it could be difficult to distinguish between trade protectionism and geopolitical considerations, which complicates matters further. The rise of trade protectionism is partly attributable to the widening wealth gap in developed economies. In the US, left-wing politicians attribute the expanding wealth gap to inequality in income distribution aggravated by liberalism, arguing that globalization benefits only a few wealthy people. In contrast, right-wing politicians emphasize external factors, claiming that Americans have been losing jobs due to illegal immigrants from Mexico and China's unfair trade practices. The common ground, nevertheless, between left- and right-wing US politicians is geopolitical considerations. Since President Donald Trump stepped up trade frictions, a bipartisan consensus began to emerge between Democrats and Republicans on the need to mitigate the US's dependence on supplies from China and restrict the export of critical technologies to China.

History doesn't repeat itself, but it often rhymes. The first wave of deglobalization came in the wake of the First World War and the Spanish flu pandemic. The rise of nationalism and trade frictions in the 1920s and 1930s eventually escalated into fascism and the Second World War. Similarly, the current wave of deglobalization has been fueled by the COVID-19 pandemic and the Russia-Ukraine conflict. In this sense, international trade and economic cooperation are conducive to not only enhancing efficiency but also world peace, since a possible alternative to market trading is resource acquisition with brute force. For a long time, economists have treated national security and market analysis as completely separate subjects. However, ongoing changes have made it necessary for economists to reexamine interactions among factor endowment, economic integration, and geopolitics.

1.2 Spatial Economy: The World is Not Flat

The "pin factory" is a well-known example of division of labor described in the first chapter of *The Wealth of Nations*. "A workman … could scarce(ly), perhaps, with his utmost industry, make one pin in a day"[4] However, things would change if "the important business of making a pin is … divided into about eighteen distinct operations".[5] In fact, the division of labor would significantly enhance efficiency and raise the factory's output to thousands of pins per worker per day. Starting from consumer goods and followed by an increasing number of intermediate goods, global industry chains came into existence through the expansion of specialization of labor and free trade from a single country to the international community. The spatial structure of an industry chain reflects not only costs incurred due to geographical distances, but also differences in factor endowment, technological progress, and institutional environment. The division of labor in global industry chains brings not only benefits but also implicit risks of instability. A key issue in the development of an industry chain is how to balance the efficiency and security of its spatial structure.

Traditional trade theories stress the effect of factor endowment from a spatial perspective, arguing that a country would gain cost advantages if it enjoys a large endowment of factors that are required in the production of its export goods. Therefore, countries with abundant labor supply would manufacture and export more labor-intensive products, while those with ample capital would manufacture and export more capital-intensive products. International trade is driven by the mutually complementary interactions between these two types of countries. Neoclassical economics, which has been the dominant economic school of thought over the past four decades, went further to assume that corporate entities' choice of production sites is based on costs of production and transportation. Therefore, capital would flow from developed economies, which offer low returns on capital, to high-return developing economies. This would result in a "catch-up effect", i.e., growth of low-income economies would outpace that of high-income ones, and international differences in labor and capital returns would diminish. Neoclassical economists believe this will eventually lead to the convergence of economic development in different countries.

Indeed, four decades of globalization have made geographical distance less important. A company or a person now faces competition not just from a single region or country, but from the whole world. In other words, the global market has become a homogeneous playing field. Thomas L. Friedman, an American political commentator and author, describes the "flattening of the world" in his book *The World is Flat* published in 2005. Friedman states that spatial distance no longer matters and that the formation of a "global village" is the prevailing trend. In a flat world, global networks and interactions would lead to harmonious coexistence, the spatial distance between countries would no longer be regarded as a big issue, and government control on national economy and society would subside.

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[4] Smith, Adam. *The wealth of nations [1776]*. Vol. 11937. na, 1937.

[5] Smith, Adam. *The Wealth of Nations [1776]*. Vol. 11937. na, 1937.

Nevertheless, the assertion that location differences no longer matter is clearly inconsistent with reality. It is important to note that only a few economies, mainly East Asian ones, successfully caught up with developed economies. Meanwhile, the trade between developed countries often outweighs their trade with low-income countries. One reason for this phenomenon is economies of scale, which require companies to increase the output of a single type of product as much as possible. However, raising the output of one type of product means a decline in the production of other goods due to limited resources. As such, there is a conflict between economies of scale and consumers' preference for variety. This problem can be mitigated through more extensive and more sophisticated division of labor and trade. Even for two countries with the same factor endowments, it is still possible to enhance efficiency through specialized division of labor and international trade. This explains the large amounts of trade among developed economies.

Another factor that interacts with economies of scale is the cost of transportation to cover spatial distances, which pushes producers to move closer to consumers and restricts the concentration of production. However, the concentration of economic activities leads to economies of scale and may benefit businesses if economies of scale outweigh transportation costs. Taking into account both transportation costs and economies of scale, it is most advantageous to develop industrial clusters in markets with abundant demand. In the early stages of China's reform and opening-up, the development of the country's manufacturing industries benefited from cheap labor. Although China's labor costs increased along with economic development and income growth, the country's status in global industry chains continued to improve thanks to its enormous market with abundant final demand.

The combination of the factors discussed above (i.e., economies of scale, diversity in consumption, transportation costs, and other distance-related costs) means that the spatial distribution of industry chains is imbalanced and that the world is not flat. We need to reexamine and recognize the importance of location. We should take into account not only economic factors (e.g., transportation costs), but also noneconomic factors (e.g., politics, society, history, and culture) from broader geographical and spatial perspectives. In addition, we should understand that business clustering shows distinct regional characteristics and disparities as it is affected by a multitude of variables such as transportation costs, economies of scale, politics, social policies, as well as path dependence. This means spatial adjustments of industry chains (i.e., reshoring, nearshoring, and friend-shoring) incur costs, including the cost of equipment relocation, the sunk cost of long-term fixed investment, as well as implicit negative externalities due to reliance on infrastructure and public services. For the aggregate economy, adjustments to industry chain usually mean lower efficiency and higher costs.

Can structural adjustments make industry chains more resilient and secure? From a micro perspective, reducing the spatial coverage and intermediate links of an industry chain can help make it more stable. From a macro perspective, however, reshoring, nearshoring, and friend-shoring are not necessarily contributors to industry chain resilience. Reshoring and nearshoring run the risk of putting all eggs in one basket, while friend-shoring might also be risky since relations between countries are unstable as well. Instead, industry chain resilience at the macro level depends on spatial diversification of supply sources, including diversification across different geographical, political, and cultural environments. The underlying reason is that risk diversification at the macro level is not diversification of sources of supply for a single type of product, but diversification of aggregate supply for the whole economy—no country is likely to produce all the goods that it consumes on its own. Compared with the age of globalization, a decline in efficiency (an increase in costs) is an inevitable consequence of adjustments to industry chains driven by geopolitics and other noneconomic factors. However, can such adjustments make industry chains more secure? The answer is uncertain, but an analogy might help: An increase in defense budgets in all countries would not necessarily improve national security for any of them.

Land is another variable that may substantially affect industry chain development going forward, although its specific effects remain unclear. More precisely, such effects stem from the role of land in climate change responses and green transition. Land provides the space for final absorption of carbon dioxide (e.g., through forest carbon sinks and carbon sequestration), as well as for production of renewable energy (e.g., solar, wind and hydro energy). The use of land (e.g., construction of reservoirs) may help people cope with floods and droughts caused by extreme weather. In addition, land is also involved in the transformation of traditional fossil energy production and related infrastructure. There are economies of scale in the manufacturing of renewable energy equipment, and the shift from fossil fuel to renewable energy may improve energy security for China. However, extensive land occupation in renewable energy utilization leads to diseconomies of scale, while climate change responses may entail substantial changes in land uses and landscapes.

For large countries, land supply does not seem to be a problem. However, it is important to note that land has special features as a factor of production. Land cannot be moved across space or transformed intertemporally, while general productive capital can transform current consumption into future consumption. In addition, land is a natural monopoly. The use of land is often associated with rent seeking, corruption, and diseconomies of scale, which distort resource allocation. For example, housing prices have skyrocketed in a few large cities even though the supply of land by mother nature is by no means in shortage. In the age of industrial economy, the role of land has declined, and neoclassical economists view land as a part of productive capital. In the new era of climate change responses, land has again become an increasingly independent factor of production. As different uses of land are pitted against each other, it remains to be seen how the new role of land affects industry chains. However, our preliminary judgement is that the growing importance of land will drive up costs due to its diseconomies of scale.

1.3 Non-Neutrality of Technology: Balancing Efficiency, Equity, and Security

Technological progress and scientific & technological innovation hold the key to success in endeavors for coping with impacts from geopolitics and climate change (green transition) on industry chains and ensuring both efficiency and security. From a spatial perspective, there are two seemingly opposing forces in scientific & technological innovations: Agglomeration and dispersion. Agglomeration manifests itself in the growth of regional centers, while dispersion is embodied in the rise of global industry chains. Economic activities in large cities show effects of agglomeration: The concentration of factors of production leads to economies of scale and scope. In particular, interpersonal interactions facilitate the emergence and spread of new ideas and technologies. On the other hand, technology shortens distance and supports spatial distribution in specialized division of labor. The rise of global industry chains results from technological progress and, in turn, fosters innovation.

Over the past 30 years, China and the US have played pivotal roles in global industry chain development and scientific & technological innovation, which can be summarized as a "G-2 model": The US has leveraged its superior strength in invention and innovation to lead the development of critical technologies, while China has taken advantage of its enormous market and production scale to rapidly expand technology commercialization and reduce costs. This has enhanced the global supply capacity and benefited consumers around the world. In addition, China has managed to shorten its distance to technological frontiers by participating in international competition and learning in both upstream and downstream sectors of industry chains. Meanwhile, profits from the Chinese market have helped US companies strengthen their innovation capabilities and maintain their leading status. Other countries also improved their economic efficiency through participation in the division of labor along industry chains. Some small economies have focused on a few niche areas to become major producers of certain products around the world.

However, the G-2 model for innovation is confronted with challenges as international technological cooperation and competition face increasingly strong impacts from geopolitics. The US government makes increasing use of its executive power to implement industrial policies. For example, the US Department of Commerce issued an "Entity List"[6] to restrict imports and/or exports. Moreover, the US government recently imposed new restrictions on exports of advanced semiconductors and related equipment, which are unprecedentedly extensive and stringent. Thus, the external environment for China's technological hardware sectors, especially semiconductors, has changed fundamentally. Under these new geopolitical circumstances, indigenous innovation is increasingly important.

An important feature of knowledge is its non-rivalrous nature, which means the use of knowledge by one individual does not affect the use by others. Therefore, scientific & technological innovation has positive externalities and characteristics

[6] https://www.bis.doc.gov/index.php/policy-guidance/lists-of-parties-of-concern/entity-list

of a public good. As a result, the private sector's investment in innovation is often insufficient. In addition, the innovation process (from initial input to final delivery) can often be lengthy, non-linear, and highly uncertain. While private institutions lack the patience and the ability to take the risk of failure, the public sector may make up for the private sector's inadequacies in the two aspects discussed above. Specifically, the government may play two roles: (1) Direct participation in innovation such as investing in R&D and education; and (2) using policy issuance and mechanism designs to create a market environment that provides incentives for innovation by private institutions.

Technology is generally believed to be neutral, i.e., neither good nor evil in itself. However, some technologies in certain key areas may be linked with political orientations as geopolitical competition intensifies. The non-neutrality of technology could also manifest itself in other areas such as social equity. Technological progress can change cost differences that result from factor endowments. When rapidly falling costs of robots make it possible for them to replace human workers, manufacturing industries may return to developed countries. Thus, developed and developing countries may manufacture the same type of product, with developed countries leveraging their abundant capital and developing countries taking advantage of their ample labor supply. Thus, the necessity of international trade would decline. While replacing human workers with machines could improve resilience in supply for developed countries, it could leave some workers at a greater disadvantage and aggravate income distribution problems among workers.

The non-neutrality of technology should also be properly handled in the development of the digital economy as some digital technologies have inherent value orientations. For example, the inventor of Bitcoin said in an email in 2008 that "(Bitcoin) is very attractive to the libertarian viewpoint…".[7] The underlying reason is that Bitcoin has the potential to become a currency that is free from government intervention and does not require authentication by a centralized and "trusted third party",[8] while encryption represents bottom-up decision-making by a multitude of individuals and computers. In contrast, artificial intelligence may help strengthen centralization as it enhances the efficiency of centralized machines that make decisions in a top-down manner. In Web 3.0, developers and users can not only interact with platforms, but also participate in platform development and governance. Compared with the modern market economy, Web 3.0 bears a closer resemblance to a community that owns means of production, distribution, and exchange.

While it remains to be seen which type of technology will dominate in the future, initial signs clearly indicate the importance of digital governance. Among major economies, the US adopts a more liberal approach to digital governance, the EU places greater emphasis on regulation, while China's methodologies are somewhere in between. As digitization has accelerated markedly since the COVID-19 outbreak, digital regulation has strengthened in various countries. Digital technologies are a

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[7] https://www.bitcoin.com/satoshi-archive/emails/cryptography/12/

[8] Satoshi Nakamoto. Bitcoin: A Peer-to-Peer Electronic Cash System. https://bitcoin.org/bitcoin.pdf

double-edged sword. On the one hand, they facilitate further division of labor and development of global industry chains, which creates economies of scale. On the other hand, they enhance governments' abilities to control and regulate economic and social activities. As the importance of geopolitics grows and national security or data sovereignty become increasingly significant issues, digital regulation and governance could exacerbate the fragmentation of the global economy. Thus, the concept of "country" could be strengthened rather than weakened in the digital era, in our view.

1.4 Economies of Scale: China's New Advantage

As discussed above, the development of international trade and global industry chains is given a boost from the combination of consumer diversity (which requires a large enough population size) and economies of scale on the production side. How are we to understand the role of economies of scale and its effect on industry chains under deglobalization trends? Economies of scale are defined as increasing returns to scale. Simply put, this means outputs are more than doubled when inputs double. The increase in production scale raises production efficiency and lowers the unit cost of products. On the one hand, the division of labor and equipment enhances labor productivity. On the other hand, a sizeable market means there is sufficient demand to help dilute fixed costs and attract investors and entrepreneurs.

By participating in global market competition, China has benefited from economies of scale in global markets and recorded strong economic growth over the past 30 years. As for smaller economies, they may in fact gain more from participation in global division of labor and cooperation. In the era of globalization, the total size of international markets for an individual company can be much larger than that of its home market. Therefore, a small economy can benefit from economies of scale by focusing on and expanding a certain industry. For example, semiconductor output accounts for around 15% of GDP in China's Taiwan region. It is inconceivable that a closed economy, without globalization, would devote one-third of its resources to a single industry instead of developing different industries. In the era of globalization and free trade after the Second World War, many small economies benefited from global economies of scale and grew rapidly into wealthy economies.

A higher degree of economic integration means a country's economic growth is less affected by its geographical size. This may explain why mainstream macroeconomic analysis in the past few decades did not pay much attention to the size of countries defined in traditional political terms. In the deglobalization era, free trade and other economic factors become less important, while noneconomic factors such as politics, culture, and history have become more significant. Thus, there is a decline in potential economies of scale that a country can enjoy by participating in division of labor along global industry chains. While this is detrimental to all countries, small economies may suffer more losses. Deglobalization has reinforced the geopolitical concept of "country", and the economy and population size of a country have become more important than before.

In the age of knowledge economy, countries with large populations have abundant human capital and can support substantial investment in R&D. With more human resources for innovation, these countries can make faster technological progress. Moreover, technological progress has a strong spillover effect, which means all industries can adopt a new technology as soon as it is born. Large countries can take greater advantage of the effect as their enormous markets mean they would have greater potential to achieve increasing returns to scale. Another advantage for large countries is that they have more people to share the costs of public goods. Low per capita costs mean that everyone has access to better public services, including infrastructure, public health, and education. In addition, large countries are better able to protect themselves and hence are more secure, while small countries may have to spend more resources on national defense, which crowds out expenditures on other public services. Moreover, different regions in a large country may help each other (e.g., via fiscal transfer payments) and are better able to cope with shocks from natural disasters or other calamities.

Deglobalization not only elevates the importance of geopolitics and national security, but also exacerbates frictions among different countries in international markets. Therefore, countries need to further leverage the original economies of scale in their domestic markets to participate in international competition. Abundant demand in large domestic markets help large countries gain an upper hand in international industrial competition. Serving global markets, in turn, expands these countries' original economies of scale. Moreover, tighter integration among different parts of industry chains in large countries may help these countries dominate more industry chains. Compared with small economies, large countries' ability to influence global industry chains and the economic landscape may actually increase in the era of deglobalization.

The *Report to the 20th CPC National Congress* states that: "We will leverage the strengths of China's enormous market, attract global resources and production factors with our strong domestic economy, and amplify the interplay between domestic and international markets and resources."[9] China is the world's second largest economy and one of the most populous countries in the world, and its labor force is as large as that of India, the US, and Indonesia combined. Therefore, it has the potential to take advantage of economies of scale, which will likely become a new growth engine for its economy going forward. However, large countries are not necessarily able to achieve economies of scale. To ensure economies of scale, competition in market economy and a consumption-led development model are essential. The Soviet Union failed to take advantage of its large population as the country's planned economy was unable to match production with consumption and lacked market competition to facilitate division of labor and trade. As a result, the former Soviet Union fell behind in its competition against the US.

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[9] *Report to the 20th CPC National Congress.* http://global.chinadaily.com.cn/a/202210/25/WS6357e484a310fd2b29e7e7de.html

To foster market competition under the trend of deglobalization, China needs to mitigate fragmentation of domestic markets and tackle new challenges posed by the shift to non-tradable sectors and the development of the digital economy. In domestic markets, measures to ensure fair access to public services and narrow the income distribution gap can help boost consumer demand and enlarge domestic consumer markets. In non-tradable sectors, it is important to note that land is a major factor that distorts resource allocation and widens the income gap due to its inherent diseconomies of scale and strong ability to capture benefits of development from other sectors. Over the past two decades, expansion of exports and the real estate sector have been important features of China's economic development. While both exports and real estate can boost short-term demand, their effects on efficiency are quite different. Export sectors compete in global markets and help enhance efficiency, but real estate undermines efficiency of the whole economy due to its natural connections to monopoly and rent-seeking behaviors.

Challenges posed by the development of digital economy include balancing economies of scale with anti-monopoly actions, privacy protection, cross-border digital governance cooperation, and other issues in relations of production. Monopoly prevention calls for measures to foster external economies of scale, cluster effects, and upstream–downstream connections rather than unlimited encouragement for scale expansion of a company. In fact, large production scale is no longer a must for efficiency enhancement since companies can now achieve this with automation and numerical control technologies, which may also help them meet diverse consumer demand more swiftly. Thus, the development of the digital economy has exhibited signs of a decline in internal economies of scale and an increase in external economies of scale. Policies for digital industries face challenges in two areas: (1) Privacy protection and the fight against unfair competition; and (2) prevention of the integration between financial and non-financial businesses in platform companies. As the financial business is license-based and receives credit guarantees from the government, the integration between financial and non-financial businesses may solidify platform companies' monopoly and distort resource allocation.

1.5 Return of Industrial Policy: New Wine in an Old Bottle

The International Monetary Fund (IMF) published in 2019 a working paper titled *The Return of the Policy That Shall Not Be Named: Principles of Industrial Policy*, which talks about governments' renewed emphasis on industrial policy. Why was industrial policy referred to as "the policy that shall not be named"? Over the past four decades, economic policies followed guidelines elaborated in the Washington Consensus, which emphasized trade liberalization, privatization, and deregulation (i.e., "big market, small government"). Against such a backdrop, industrial policy became highly controversial and was even "tainted with bad reputation".[10] In the past two years, however, governments' roles in social and economic activities have expanded substantially due to responses to COVID-19. In addition, governments of various countries have issued an increasing number of special policies targeting certain industries amid the rise of protectionism and geopolitical forces. The return of industrial policy has become a consensus and is bound to have a major impact on the development of the global industry chain.

In market economies, industrial policy can guide resource allocation at different levels. Historically, various countries adopted a wide variety of industrial policies, some of which were successful, while others failed. After the Second World War, the world saw a decline in trade protectionism, notably the removal or reduction of tariffs and non-tariff barriers. However, Japan and South Korea adopted an alternative form of protectionism—restrictions on foreign direct investment (FDI). Meanwhile, European countries and Japan attached importance to state-owned enterprises (SOE) for some time. In fact, the governments of France and Japan formulated development programs similar to China's Five-Year Plans (FYP). Some European countries provided support for the development of small- and medium-sized enterprises (SME) via public banks, while Latin American countries adopted import substitution policies in the 1970s. The US government provided strong support for R&D, and its national defense budget was a major source of R&D spending. particularly during the Cold War. In view of outcomes over the following decades, such government support for R&D was arguably the strongest industrial policy in the world.

How are we to understand industrial policy's functions under new circumstances? Three dimensions merit attention: (1) Protectionism to bolster domestic employment and income: From the perspective of developed countries, a popular view is that globalization has eroded employment in high-income industries such as manufacturing. In the past, the main solution adopted for this issue was to remedy it with social policies such as improvements to education, training, and social security. Nowadays, greater attention is being paid to policies targeting specific industries to change their competitive landscapes. (2) Policies addressing externalities and market failures: Policies in two areas warrant special attention: Government investment and supportive measures to foster scientific & technological innovation, and policies to facilitate carbon emissions reduction and green transition. (3) Geopolitical rivalry: Technological competition is a key aspect of this issue. The three dimensions discussed above are entangled with each other. For example, geopolitics is often connected with protectionism. Therefore, industrial policies exhibit a distinct external orientation and have direct or indirect links with international trade and investment.

In developed countries, notably the US, government policies for scientific & technological innovation have recently exhibited three noteworthy features: (1) In-depth government participation via increased R&D budgets and subsidies for the manufacturing of certain high-tech products. (2) Exploration of various funding models to

[10] Reda Cherif and Fuad Hasanov: *The Return of the Policy That Shall Not Be Named: Principles of Industrial Policy,* IMF Working Paper, March 2019 https://www.imf.org/external/pubs/ft/wp/wp97118.pdf

support R&D and innovation. Industrial policies are often integrated with incentives to motivate risk-taking by private enterprises. The US government's policies for some research areas are similar to the resource mobilization amid the space race against the Soviet Union during the Cold War. (3) Government measures to help the country benefit more from innovation and technological progress, including restrictions on the export of advanced technologies and encouragement for domestic production. For example, the US has not only restricted the export of semiconductor technologies but also provided subsidies for the reshoring of chip production back to the US. The US's industrial policies are clearly extending from upstream R&D expenditures to specific midstream and downstream industries.

Confronted with restrictions and competition from the US, China has attached greater importance to scientific & technological innovation. According to the *Report to the 20th CPC National Congress*, "innovation will remain at the heart of China's modernization drive".[11] The report stresses that China will "improve the new system for mobilizing resources nationwide", boost its "strength in strategic science and technology", and "deepen the structural scientific and technological reform" to create "an open and globally-competitive innovation ecosystem".[12] As the world's largest and second largest economies, the US and China are both expanding their industrial policies from familiar areas (innovation and R&D for the US, manufacturing for China) to less familiar realms. Meanwhile, the world's major economies have set clear timetables for reaching peak carbon emissions and carbon neutrality. Correcting the global externality of carbon emissions not only requires scientific & technological innovation but also involves transformation of traditional industries. Measures addressing these issues may be the most important industrial policy over the next few decades. More and more signs show that industrial policies in various countries are increasingly systematic and comprehensive.

Apart from tremendous policy attention and increased investment, the key to success lies in the efficiency of policy implementation. Innovation is a special undertaking as it is highly uncertain and requires long-term investment, which calls for a close partnership between public and private sectors. Therefore, policy makers should take into account both incentives and penalties, while innovators and technological staff should be granted excess returns to some extent. For example, they can be allowed to share part of the intellectual property income from government-sponsored projects, in addition to the normal pay for their work. Meanwhile, government-sponsored technological R&D projects should have proper evaluation, tracking, reward, and penalty mechanisms, including conditional subsidies and sunset clauses.

The creation of a sound innovation ecosystem requires support from other policies so as to establish proper incentive and motivation mechanisms for innovation in the whole society. In China, policies in two interconnected areas are the most noteworthy. The first is the correction of distorted resource allocation caused by excessive

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[11] *Report to the 20th CPC National Congress.* http://global.chinadaily.com.cn/a/202210/25/WS6357e484a310fd2b29e7e7de.html

[12] *Report to the 20th CPC National Congress.* http://global.chinadaily.com.cn/a/202210/25/WS6357e484a310fd2b29e7e7de.html

marketization of the real estate sector. The key to solving this problem is establishing new real estate development models, increasing the supply of low-income housing, encouraging both rental housing and home purchases, and imposing property tax on the demand side. This would result in steady streams of revenue from land replacing proceeds from the sale of land use rights as an important source of income for local governments. The second noteworthy area is the improvement of financial structures, especially the separation of financial business from industrial sectors, and the separation of various financial sub-sectors from each other. The first separation prevents the government's credit guarantee for commercial banks from extending to industries in the real economy, and the second prevents such guarantee from extending to capital markets. With these improvements, the financial system would better serve the real economy, and capital markets would be more conducive to innovation.

China has entered a new stage of development with five key words in its new development philosophy: "innovation, coordination, greenness, openness, and sharing". This means the country's economic development targets not only efficiency but also equity and security. The CICC Research Department and CICC Global Institute have collaborated to issue a whole series of in-depth reports on major topics in the new stage of development, including *Digital Economy: The Next Decade, Guidebook to Carbon Neutrality in China, The Rise of China's Innovation Economy,* and *Building an Olive-shaped Society (Chinese version).* This new report on industry chains is the latest research project in this series, and we hope it will facilitate discussions on relevant topics. Your comments, suggestions, and criticism would be highly appreciated.

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Chapter 2
Overview of the Industry Chain: From Efficiency to Security

Abstract Division of labor and the ability to facilitate transactions lie at the heart of industry chains, supply chains, and value chains. Two major factors that determine how the division of labor and transactions unfold globally are efficiency and security. We can see from the history of industrial development that companies and markets are able to continuously improve efficiency by optimizing the division of labor and transactions, through which they can dominate the development of industry chains. Differences in factor endowments and equalization of factor prices among countries determine how industry chains are developed around the world under the principle of efficiency.

China's reform and opening-up have improved the efficiency of its industry chains both domestically and internationally. Domestically, reforms have enhanced China's marketization and industrial agglomeration, thereby unleashing the country's economic efficiency. Internationally, opening-up has propelled China's participation in the global industry chain and its cooperation with developed countries, resulting in the country becoming one of the leading forces of globalization.

How should we understand the security of industry chains and supply chains? From the enterprise perspective, security is mainly associated with maintaining the stability of supply chains. From the perspective of governments, security is to ensure the country's industrial and technological superiority as well as independence from international competition, which is to some extent related to the backdrop of rising geopolitical risks.

After years of efficiency gains, China and the US's pursuit of industry chain security somewhat goes against the principle of efficiency in the context of global industry chains, thereby necessitating efforts from both countries to control the resulting loss of efficiency. The two countries need to maintain bilateral economic and trade relations as well as the global trade system at the economic level.

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Technological decoupling between countries would hinder technological progress and economic growth on both sides. However, the fundamental factor that determines a country's technological progress lies in its national innovation system, which consists of the government, the market, universities, and companies. Ultimately, industrial competition between countries is competition in innovation.

Keywords Industry chain · Supply chain · Deglobalization · Efficiency · Security

Efficiency and security are the two major factors behind geographical layout and the development of different industries. China's reform and opening-up have greatly improved the efficiency of its economy. The economic and trade cooperation between China and the US has played a major role in globalization since the 1990s. However, the world today is seeing signs of deglobalization. As China's economy continues to grow, and its industries are continuously upgrading, the two countries are gradually shifting from cooperation to competition. This is bound to have an impact on the configuration and distribution of global industry chains. When countries are committed to global peace and development, economic and trade cooperation is generally adopted internationally, and efficiency improvement is the primary focus of industrial development. However, when international geopolitical risks rise, so do concerns about security. From the perspective of enterprises, industry chain security is mainly associated with maintaining the stability of supply chains, shifting their strategies from just-in-time to just-in-case. From the perspective of governments, industry chain security is related to competition among countries. Every country wants to ensure its industrial and technological superiority in international competition to a certain extent. The pursuit of industry chain security by China and the US in the context of mutual competition may come at a cost of a certain level of efficiency loss. However, both sides cannot pursue security at any cost, and need to control the loss of efficiency. In this chapter, we examine the concepts and theories related to the efficiency and security of industry chains, and try to provide a framework for analysis and understanding of the efficiency improvement during China's industrial development in the past four decades as well as the security issues currently faced by the country.

2.1 The “Efficiency First” Principle of Industry Chains

2.1.1 Division of Labor and Transactions Are at the Core of Industry Chains, Value Chains, and Supply Chains

An industry chain can be understood as an interrelated system formed by enterprises that produce various products or provide various services through the division of labor and transactions. From the macro perspective, the relationship between industries is neither chain-like nor net-like, but an intertwined formation depicted by the input–output table. Understanding the shape of industry chains from a macro and systemic perspective is crucial to the discussion of policies related to industry chains.

Supply chains and value chains are closely related to industry chains. A supply chain is characterized by the supply relationships between enterprises in an industry chain. It can be an upstream-downstream chain or a supply network. Compared to an industry chain, a supply chain highlights the materials that are the focus of corporate supply management. In contrast, a value chain refers to the value distribution in an industry chain, i.e., the distribution of product value among different enterprises in the industry chain. If the enterprises in an industry chain are located around the world, they constitute a global value chain. For example, Apple organizes numerous companies through its design, procurement, production outsourcing, marketing, and sales, collectively forming the iPhone industry chain. The supply relationships and management of various components involved in the iPhone manufacturing process, such as procurement, transportation, warehousing, and insurance, constitute the iPhone supply chain. The enterprises involved in iPhone manufacturing receive different portions of the product price, thereby forming the value chain of the iPhone industry chain.

The concepts of industry chain, value chain, and supply chain all reflect the fundamental characteristics of modern industries: The production process of modern goods involves complex division of labor and transactions. If we are talking about classical goods such as wine and wool, which often appear in the works of classical economists, then we do not need the concept of industry chain, nor do we use the concepts of supply chain and value chain. The production process of these classical goods involves simple division of labor, mostly within a single production unit. Because of such simplicity, transactions during the production process are also relatively simple. However, the production of modern goods such as cars, mobile phones, and computers often involves a large number of intermediate goods and services. Most modern goods need to go through complex division of labor and transactions before reaching consumers, and their production often requires the collaboration of dozens of companies. Due to sophisticated division of labor, the production process of these goods requires high complexity in transactions between enterprises and management strategy within enterprises. This production process for modern goods, based on complex division of labor and transactions, is what the concepts of industry chain, value chain, and supply chain have in common.

2.1.2 Efficiency of Industry Chains: Transaction Costs, Geographical Factors, and Economies of Scale

The complex structure of industry chains is the result of the pursuit of economic efficiency. Industry chain configuration under the "efficiency first" principle places efficiency improvement as the top priority. In a sense, economic efficiency is almost identical to the degree of division of labor and transactions. Adam Smith's profound illustrations in *The Wealth of Nations* shed light on this matter: "But whatever division of labor can be introduced always creates a proportionate increase of the productive powers of labor… Because the power of exchanging is what gives rise to the division of labor, the extent of this division must be limited by the extent of that power—i.e., by the extent of the market."

Now that the scope of market transactions determines the extent of division of labor, and the division of labor increases efficiency, why not organize all of the division of labor through market transactions rather than placing some of the process within enterprises? It is Ronald Coase who raised and answered this question. The "efficiency first" principle, from the perspective of enterprises, is reflected in the pursuit of profit maximization or cost minimization. As the division of labor became increasingly complex, the management costs of enterprises were gradually split from production costs and analyzed separately. Coase was the first to notice another cost in economic activity: Transaction cost. While the market facilitates the division of labor and increases efficiency, there is no free lunch. To make a transaction, one needs to search for a counterparty, negotiate contract terms, sign the contract, and ensure its execution. A party that breaches the contract would be held liable. All these procedures entail costs. Although the division of labor through market transactions improves efficiency and reduces production costs, it increases transaction costs. However, while organizing the division of labor within enterprises through instructions for management from supervisors would lower transaction costs, it would also increase management costs. The equilibrium between management costs and transaction costs at the margin determines the boundary between enterprises and the market. Among transactions costs, the most important part is the cost incurred to overcome information asymmetry. This is because the completion of transactions relies on the trust between parties, but people do not fully know each other and rarely share the same information, forcing people to spend time, effort, and money to build trust. This opens the door to the new institutional economics. A good institution can reduce the cost people pay to build trust, facilitate transactions and the division of labor, and raise efficiency. Therefore, institutions as the sum of norms that influence people's economic behavior determine the level of efficiency and the form of industry chains.

Transportation costs also play an important role in the configuration of industry chains. Where enterprises decide to have their supply chains and how they are managed are largely determined by their aim to reduce transportation costs. However, transportation costs have long been overlooked by economics. Johann Heinrich von Thünen, a nineteenth-century economist, pioneered economic geography with his theory of freight costs influencing agricultural distribution and land rents in *The*

Isolated State. Nevertheless, economic geography as an area of study did not follow the path Thünen had started. Instead, it focused on the analysis of specific cultural-geographical particularities. It was not until Paul Krugman published his book *Geography and Trade* in 1991 that spatial factors were re-introduced into the analysis of trade and production, and the new economic geography was born. Krugman argued that transportation costs lead to increasing returns to scale, i.e., economies of scale, in spatial agglomeration of production. The new economic geography attributes economies of scale to underlying factors such as geographical space and transportation costs, rather than spillover effects and positive externalities that are yet to be explained in depth.

2.1.3 International Configuration of Industry Chains: Comparative Advantages, Economies of Scale, and Multinational Corporations

The division of labor and transactions can take place across national borders, and in fact, trade activities predate the origins of countries. The international order formed by trade rules and geopolitics constitutes a broad "system" that determines international transaction costs and influences the form of global industry chains. At the heart of classical trade theory is David Ricardo's theory of comparative advantage, which argues that trade should take place between countries with different factor endowments, and countries essentially "export" their relatively abundant factors and "import" their relatively scarce ones through trade. However, Bela Balassa observes that intra-sector trade in similar products has grown between countries with similar factor endowments after the Second World War.[1] Because of increasing returns to scale, industrial countries with similar resource endowments have become more specialized in the production of goods within a sector, and enjoyed economies of scale brought about by the international market. As such, economies of scale have become another force driving international trade and division of labor apart from comparative advantage. Before the First World War, international trade mainly took place between industrial countries and resource countries, with comparative advantage playing a dominant role. After the Second World War, with various institutional arrangements for trade liberalization, there was a growing trend of intra-sector trade between industrial countries as companies pursued economies of scale.

We can understand international trade as a kind of cross-country arbitrage in essence. Production costs of goods vary in different countries due to distinctions in factor endowments, creating room for arbitrage. Arbitrage activity reduces room for arbitrage, that is, international trade leads to equalization of factor prices across countries. However, Paul Samuelson has found that if differences in factor endowments between two countries are large enough, international trade would not be able

[1] Balassa, Bela. "Tariff reductions and trade in manufacturers among the industrial countries." *The American Economic Review* 56. 3 (1966): 466–473.

to fully realize cross-country arbitrage from factor price differences.[2] If international trade cannot fully realize the potential efficiency gains, the "efficiency first" principle would open up other paths. In the past few decades, the progress in information technology and the deepening of globalization greatly reduced management and transaction costs, and expanded the scope of companies and markets. As such, multinational corporations (MNCs) have emerged. MNCs transfer capital and proprietary assets associated with capital, including technology, management know-how, and market channels, from capital-abundant countries to labor-abundant countries, forming the international configuration of industry chains. Elhanan Helpman points out that the emergence of MNCs and the accompanying capital flows have led to sufficient cross-country arbitrage, equalizing factor prices even in two countries with very different factor endowments.[3] The dominance of MNCs in the global configuration of industry chains has led to an unprecedented manifestation of the "efficiency first" principle.

The emergence of MNCs requires not only sufficient economic incentives, but also technological, institutional, and geopolitical conditions. On the technological front, the information technology revolution made it possible to manage industry chains on a global scale. On the institutional front, the signing of the General Agreement on Tariffs and Trade (GATT) after the Second World War and the establishment of the World Trade Organization (WTO) in 1995 paved the way for lowering tariffs and advancing regional collaboration. On the geopolitical front, the improvement in China's relations with the US and other Western countries in the 1970s, the independence of Eastern European countries from the Soviet Union and the end of the Cold War in the late 1980s, ushered in peace and development as prevailing themes in the world. The rise of MNCs in the 1990s was closely related to the various conditions at the time.

2.2 Globalization and Deglobalization

2.2.1 China Becomes the World's Factory by Improving Efficiency

The new economic geography pioneered by Krugman in 1991 is essentially an economic theory of manufacturing development. It almost perfectly predicted the path of development of China's manufacturing industry in the following two decades. By calculating the change in the total factor productivity (TFP) of China's industrial enterprises, we find that the rapid development of China's manufacturing industry after the 1990s well reflects the efficiency gains brought by the agglomeration effect

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[2] Samuelson, Paul A. "International factor-price equalisation once again." *The economic journal* 59. 234 (1949): 181–197.

[3] Helpman, Elhanan. "A simple theory of international trade with multinational corporations." *Journal of political economy* 92. 3 (1984): 451–471.

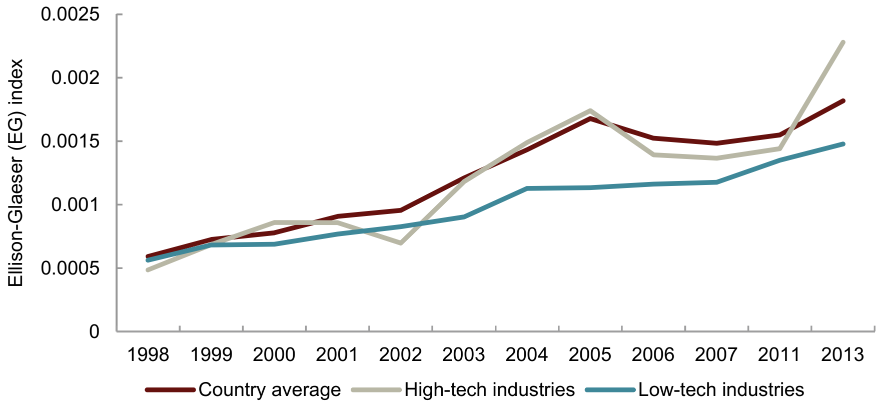

Fig. 2.1 Spatial agglomeration of China's industrial system increased. *Note* Spatial agglomeration is measured by the Ellison-Glaeser (EG) Index based on the National Bureau of Statistics' industry classification standard. The values of high-tech and low-tech industries are the average values of the EG Index for corresponding industries. See Ellison, Glenn, and Edward L. Glaeser. "Geographic concentration in US manufacturing industries: a dartboard approach." Journal of political economy 105.5 (1997): 889-927. *Source* Chinese Industrial Enterprise Database, CICC Global Institute

and the regional division of labor (Fig. 2.1). The country's ability to achieve agglomeration effect can be attributed to the market mechanisms and liberalized market transactions introduced by China's reform and opening-up. This, coupled with the large number of migrant workers in coastal cities, promoted industrial agglomeration and achieved economies of scale. Entering the 1990s, China set up capital markets, advanced reforms in the modern enterprise system, fostered the development of the private sector, and phased out state-owned enterprises in most industries. These market-oriented institutional reforms laid the foundation for China's accession to the WTO. In 2001, China joined the WTO, marking full participation in the division of labor in global industry chains, which further boosted its economic efficiency. The country became a global manufacturing hub within just a few decades.

China's accession to the WTO was crucial for it to improve its economic efficiency. The combination of comparative advantages and economies of scale has greatly improved not only China's economic efficiency, but also the efficiency of global industry chains. Some Chinese towns along the country's southeastern coast have become global manufacturing hubs for a particular product. For example, Xidian, a town in Ninghai county, Zhejiang province, produces 70% of China's flashlights and exports its products worldwide. Among the town's 110,000 people, 60,000 of them are migrant workers. China's industrial enterprise data shows that foreign companies in the country gradually lost their leading edge in TFP to local Chinese companies after China's accession to the WTO, and were eventually overtaken by local Chinese companies (Fig. 2.2).

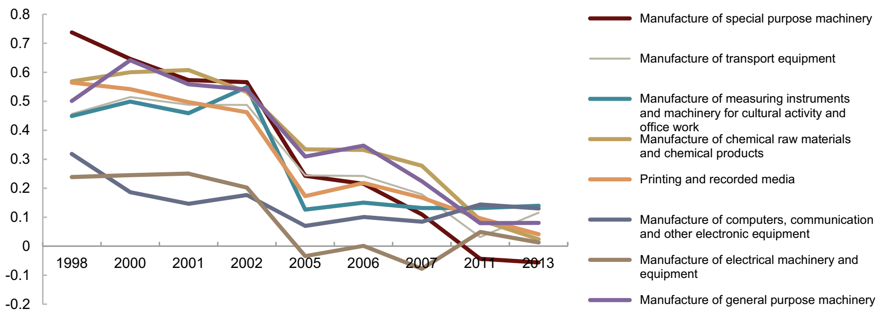

Fig. 2.2 Difference in the average TFP between domestic and foreign companies in high-tech industries. *Source* Chinese Industrial Enterprise Database, CICC Global Institute

2.2.2 China-US Cooperation is the Main Thread of Globalization

The term globalization is used to describe the tendency of integration in the world economy, politics, and culture. The globalization that people now talk about mainly refers to the globalization since the end of the Second World War. This process can be divided into two phases, with the end of the Cold War as the dividing line. In the first phase, international organizations such as the United Nations, International Monetary Fund, World Bank, and GATT were established, and there was a certain degree of collaboration in global politics as well as the global economy. However, globalization did not fully unfold amid the confrontation between the US and the Soviet Union. In the second phase, after the end of the Cold War, economic and trade relations went beyond international trade, and the rise of MNCs brought about the global configuration of industry chains, creating conditions for equalization of global factor prices as revealed by Helpman. From an economic perspective, the second phase of globalization has truly reflected the tendency of integration in the world economy.

The most distinctive feature of globalization is China's partnership with developed countries led by the US, and China's rise as one of the world's largest economies. The macro-level mechanism behind this is as follows: (1) The substantial differences in factor endowments between China and the US created the largest cross-border arbitrage opportunities in the world, while trade in finished goods was not sufficient for fully realizing the cross-border arbitrage; (2) MNCs and cross-border capital flows adjusted the distribution of industry chains between China and the US, which is the essential thread of this round of globalization. This story is perfectly illustrated by the macroeconomic performance of China and the US. First, China and the US are the two largest trading partners in the world. Second, the US is the world's largest foreign investor, while China is the country with the largest capital inflows other than the US. From 1995 to 2022, the US's cumulative foreign direct investment (FDI) inflows and outflows both exceeded US$5trn, ranking No.1 in the world; the Chinese mainland

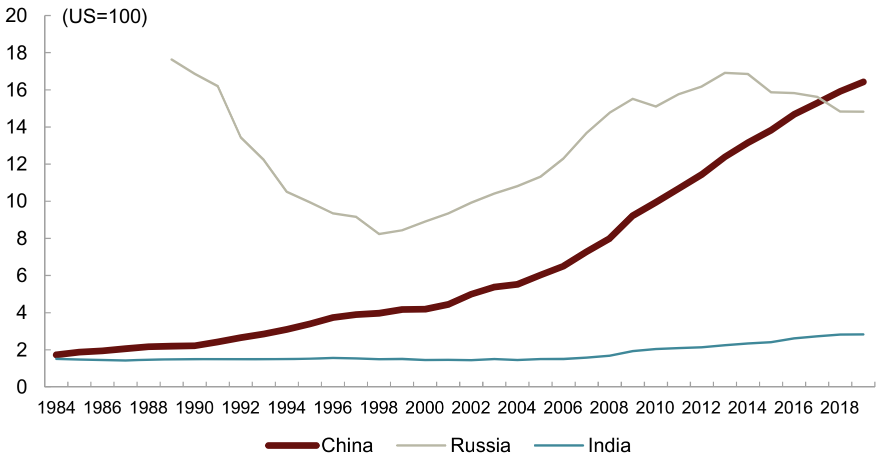

Fig. 2.3 Per capita labor income in China, India, and Russia since 1984. *Source* Wind, Federal Reserve Economic Data, CICC Global Institute

and Hong Kong SAR combined recorded about US$5trn of cumulative FDI inflows; the Chinese mainland recorded US$2trn of cumulative net FDI inflows, the largest in the world.

Thomas Friedman's argument that "the world is flat"[4] is in fact a reflection of factor price equalization between China and the US. As Helpman predicted, there was a rapid equalization of factor prices between China and the US as a result of cross-border capital flows. In fact, China was the only large economy that continued to significantly narrow its labor income gap with developed countries over the past 40 years. China's labor income per capita was less than 1% that of the US in 1984, but has risen to about 20% that of the US in 2021 (Fig. 2.3), demonstrating a significant increase. Over the same period, India and Russia, two other large economies, failed to achieve the same large increase in labor income as China did. Moreover, China's large population has played a vital role in the evolution of globalization. China had sufficiently different factor endowments from those of developed countries, making it a more desirable destination for cross-border arbitrage than Russia and Eastern European countries. After the Cold War, MNCs flocked to China, and the combination of international capital and China's cheap labor drove rapid development of the country's manufacturing industry.

China's wise decisions in assessing the situation and adapting accordingly were essential to the country's emergence as a leading force in globalization. China normalized its diplomatic relations with Japan in 1972 and established diplomatic relations with the US in 1979. The improvement in China's diplomatic relations with developed countries was a prerequisite for economic and trade cooperation. Moreover, the improvement of cross-strait relations in the 1980s created a supportive environment

[4] Friedman, Thomas L. *The world is flat: A brief history of the twenty-first century*. Macmillan, 2005.

and attracted a large number of companies from the Taiwan region of China to invest in the Chinese mainland, providing capital for the Chinese mainland's economy to take off. China started its reform and opening up in the 1980s and implemented a series of market-oriented reforms in the 1990s, paving the way for its WTO accession in 2001. China's reform and opening up, coupled with international geopolitical conditions at the time, created the country's economic miracle. Economic and trade ties are the ballast of China-US relations. This speaks to the fact that the economic and trade ties between China and the US, which are based on the substantial differences in factor endowments, are the basis for win–win cooperation between the two countries.

2.2.3 Deglobalization: China and the US Shift From Cooperation to Competition

China and the US are major winners of globalization. The main benefits that China has gained from globalization are substantial growth in household income and technological progress in the manufacturing industry. The main benefits for the US are growth in corporate earnings and stabilization of price levels. MNCs' industry chain distribution between China and the US has brought substantial profits to US companies. In constant prices, US corporate earnings increased nearly 40-fold in the past two decades (Fig. 2.4). However, ordinary US workers have not benefited much from globalization, or have even suffered in relative terms. US labor income growth has lagged far behind profit growth, and labor income as a share of US GDP has declined significantly since 2001 (Fig. 2.4). The stagnation of income growth for ordinary US workers has to some extent been masked by low inflation, as low-priced manufactured goods from China depressed long-term inflation in the US. This "Hillbilly Elegy" in the US has allowed populist political leaders to come to power.[5]

China's factor endowments have also changed during the process of globalization. Labor and capital are the most important factors in manufacturing. On the labor side, China's working-age population began to decline in 2016, and the country's labor costs began to rise even earlier (i.e., the "Lewis inflection point"). After nearly four decades of family planning, China has switched its labor force advantage from quantity to quality. Government and family investment in education has significantly raised the educational level of the labor force. Compared to 1980, the quality of China's labor force has improved substantially despite the shrinking quantitative advantage. On the capital side, China's capital-output ratio (capital stock divided by GDP) has approached that of the US after rising in the past four decades (Fig. 2.5), and China is no longer a capital-scarce country. The narrowing of differences in

[5] J.D. Vance's 2016 book *Hillbilly Elegy* details how blue-collar workers in the US's "rust belt" have been impoverished as the country's industrial centers declined. Former US Treasury Secretary Lawrence Summers believes the US socioeconomic context depicted in the book provides a clear explanation for Trump's rise to power.

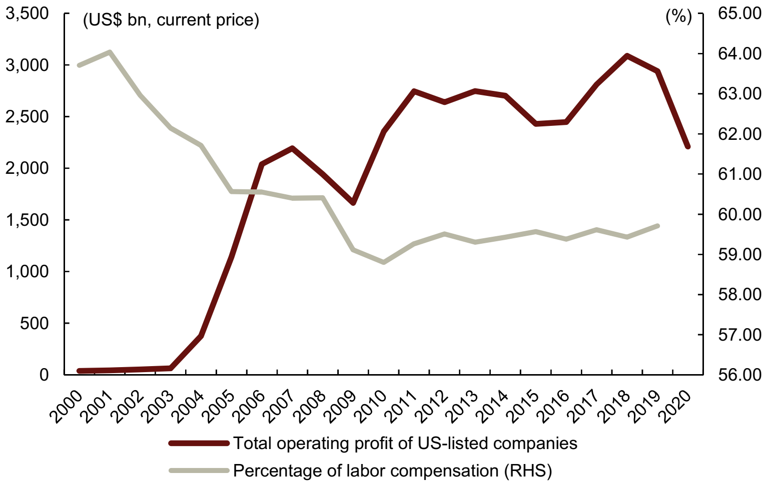

Fig. 2.4 Return on capital and labor compensation in the US. *Source* Wind, Federal Reserve Economic Data, CICC Global Institute

factor endowment between China and the US means shrinking room for cross-country arbitrage by MNCs and capital flows. When differences in factor endowment between China and the US narrow to a certain degree, further equalization of factor prices between the two countries can be achieved simply through trade in manufactured goods. In this sense, the narrowing of economic differences between China and the US has to some extent reduced the role of globalization in promoting economic efficiency.

As China-US cooperation was the main theme of globalization in the last couple of decades, the main theme of deglobalization is the shift from cooperation to competition between the two countries. China's sizable labor force, multiplied by its rising labor productivity, puts the country in a position to catch up with the US in GDP

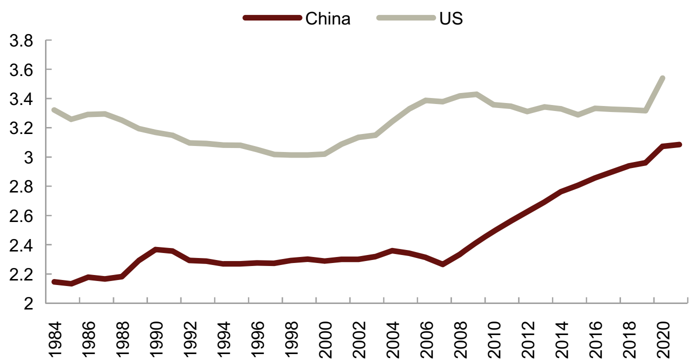

Fig. 2.5 Capital-output ratios of China and the US. *Source* Wind, Haver, CICC Global Institute

terms. China's GDP at purchasing power parity (PPP) has already surpassed that of the US. Since the US economy is dominated by the service sector and the Chinese economy is dominated by the manufacturing sector, China has also surpassed the US in terms of GDP from material production. As China catches up with the US in economic terms and the two countries' factor endowments converge, there has been some overlap in the roles of China and the US in the global economy, intensifying competition between the two countries. Increased economic competition, in turn, tends to bring the risk of geopolitical conflicts. Because of the fundamental significance of China-US cooperation in globalization, China-US relations serve as a ballast for the world economy. If the cooperative relationship between China and the US changes, the world economy may face certain disruptions.

2.3 Industry Chain Security Concerns: Controlling the Loss of Efficiency

2.3.1 Industry Chain Security: Understanding From Different Perspectives of Companies and Governments

Industry chain security is generally understood as the resilience and robustness of supply chains. This understanding is mainly from a micro perspective of enterprise management and emphasizes the smooth operation of MNCs' transportation, logistics, warehousing, and production processes. The earthquake that hit Japan on March 11, 2011 led to a temporary breakage in many industry chains, sounding the alarm of global industry chain breakage for the first time. The COVID-19 pandemic caused disruptions to industry chains and supply chains, again triggering security concerns. In response to the increasingly normalized supply chain disruptions, MNCs are shifting their supply chain strategies from minimum inventory and just-in-time to just-in-case by taking measures to increase the redundancy and diversification of supply chains. These measures include increasing inventory and spare production capacity, adding suppliers, and expanding the geographical distribution of production capacity, among other efforts. Essentially, this pursuit of industry chain security can be regarded as management adjustment (from the perspective of companies) to combat tail risks, and its core concept is still to maximize the risk-reward of companies, which is not contradictory to the "efficiency first" principle.

Industry chain security from the perspective of governments is different from that from the perspective of companies. The US government's industry chain security policies go far beyond the scope of enterprise management. The US government has stated that its aim is to enhance the country's competitive advantage and leadership in the global economy, and to ensure its leadership in technological innovation.[6]

[6] US Innovation and Competition Act of 2021, https://www.congress.gov/bill/117th-congress/house-bill/4521/text

This understanding of security apparently goes beyond the issues of supply chain resilience or robustness typically discussed in the literature. For China, there is no clear definition of industry chain security at the national level, and the government's emphasis on industry chain security is often aimed at ensuring controllability in core technologies in important industries, a pursuit largely in response to the US's threat of "decoupling". China's industry chains use US technology extensively in product manufacturing and R&D. The US has long been the largest source of China's technology imports. Net US exports of intellectual property royalties to China reached US$8.25bn in 2021, while China's exports of intellectual property royalties to the US were only US$520 mn in the same year.[7] This asymmetry allows the US to use "decoupling" as a threat, and China has to deal with this risk.

Government-level considerations of industry chain security may be inconsistent with the efficiency principle. Such inconsistency has two possibilities. One is that there may be a contradiction between efficiency and security on different time horizons. The pursuit of efficiency is generally reflected in corporate behavior to maximize profits, but entrepreneurs may focus too much on short-term goals and corporate behavior may pose industry chain security issues in the long term. The other is the fallacy of composition. While efficiency and security are consistent from an individual perspective, they could be inconsistent from an aggregate perspective. The market behavior of companies under the "efficiency first" principle, when added up, may be in conflict with the pursuit of security from the perspective of the entire economy. The contradiction between security and efficiency is also reflected in the fact that the pursuit of security goals is sometimes at the expense of efficiency. In particular, security considerations that are focused on ensuring controllability to a large extent mean reducing transactions and division of labor, which are sources of efficiency. Therefore, the pursuit of ensuring controllability could lead to a certain loss of efficiency.

The government's formulation of industrial policies from a security perspective can be seen as a kind of market intervention to provide public goods. A typical example of security is national defense, which is also a classic example of government provision of public goods. When major economies all understand industry chain security as controllability, the concept of security is linked to geopolitical factors and becomes more comparable to national defense. The industry chain security considerations of the Chinese and US governments are to some extent both related to rising global geopolitical risks. Due to the uncontrollable nature of geopolitical risks, industry chain security is to some extent tied to national security. The impact of geopolitical conflicts on industry chain security is mainly manifested in the risk of export bans faced by a country. For example, Russia could ban its energy exports to Europe, and the economic sanctions imposed by Europe and the US on Russia are in a sense also export bans. Once industry chain security is linked to national security due to geopolitical risks, it is no longer subordinated to the "efficiency first" principle as cost–benefit considerations would to some extent be put aside.

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[7] Based on the data of contract value of China's technology imports. See China Statistical Yearbook on Science and Technology 2021 for details.

2.3.2 Coping with Security Challenges From Rising Geopolitical Risks With a National Innovation System

The end of the Cold War created favorable geopolitical conditions for deepening globalization, but the current global geopolitical landscape is changing in the direction of deglobalization. The Russia-Ukraine conflict has led to a significant rise in global geopolitical risks. In this context, economic participants are set to intensify their pursuit of security if their risk appetite remains unchanged. Therefore, companies' industry chain and supply chain management need to be more resilient and robust. Governments also need to make more efforts and investments to pursue industry chain security.

In the context of rising geopolitical risks, many countries naturally regard controllability of industry chains as a security goal. However, given the complex division of labor and transactions in global industry chains, at present, almost no country can achieve full controllability in all important industries and technologies. Even the US has not really achieved this in all important industries. At the beginning of the COVID-19 pandemic, the US experienced a serious shortage of production capacity for masks, respirators, and some medical devices, and had to rely heavily on imports.

How should we measure industry chain security? There is no standard metric for this due to the different aspects of security. Terms of trade, concentration ratio of imported products, and market concentration ratio of exported products can be used to measure a country's industrial competitiveness and dependence on other countries. People often use the localization rate of a product or an industry to measure the degree of controllability. However, it is worth noting that all these metrics are somewhat one-sided. In particular, we should not forget that an industry chain is essentially a starry sky-like industrial system with macro characteristics, and the localization rate is only a static metric. Excessive pursuit of the localization rate of a product or an industry is likely to miss the forest for the trees.

Industry chain security issues that are geopolitically related essentially involve technological competition between countries. From the US's perspective, industry chain security is centered on maintaining technological superiority. From China's perspective, industry chain security lies in catching up technologically. The two countries' industry chain security considerations fundamentally lie in technological competition. Recognizing this, we do not need to overly worried about China-US decoupling. The US's industrial reshoring and friend-shoring policies might not contradict China's security and efficiency. As noted earlier, the geographical distribution of industries is largely subject to the laws revealed by the new economic geography. A large number of MNCs moved their production bases to China starting in 1990s, mainly in light of China's factor endowments at the time. As China's economy develops and factor endowments change, some MNCs and even local Chinese companies are relocating part of their businesses to other countries. This is a natural result of economic development and does not necessarily hurt China's industrial efficiency and security.

Technological decoupling between the US and China indeed poses a security challenge to China's economy. This is not a security challenge that would put China's economy in danger of collapse, but one that would mainly limit the pace of China's economic development and capacity to improve its innovation. For example, US restrictions on high-end chip exports to China will not halt China's economic growth or cause a major recession in China's economy. The damage of such technological decoupling to China is that it would curb the growth rate of China's technological innovation, but it should not wipe out China's ability to advance technologically.

There is a long history of technological competition between countries, and this is fundamentally competition between national innovation systems. Any existing technology is bound to be replaced by new technology. Even if a country is able to monopolize an existing technology, it does not mean that it will be able to monopolize new technology. Future technological advantages will arise from areas of science and technology that are still unknown to us today. Therefore, technological competition between countries essentially does not lie in particular technologies, but lies in countries' ability to systematically generate new knowledge, new technologies, and new products. A country's ability to innovate depends on its own innovation system and is not subject to external restriction on a particular technology. The key to achieving controllability does not lie in achieving these in particular technologies, products, or industries, but lies in establishing an effective national innovation system to ensure the constant generation of economically viable innovative technologies and products. The national innovation system is an ecosystem composed of government, universities, companies, and the market. Fiscal spending, finance, and software and hardware infrastructure play important roles in the national innovation system. The roles of the market and the government are both indispensable and need to be coordinated. The market plays a fundamental role, and the government needs to make up for the failure of market mechanisms in basic research.[8]

2.3.3 Orderly Competition Between China and the US: Controlling Efficiency Losses From Deglobalization

Deglobalization inevitably leads to efficiency losses. Historically, when major economies shifted from cooperation to competition, it often impeded the global flow of goods and factors, leading to a decline in international trade and investment. The post-First World War setback in globalization continued until 1937 and spanned the entire Great Depression. During this period, international trade and associated fund flows declined significantly (Fig. 2.6). How could China and the US minimize efficiency losses while pursuing security? An important manifestation of deglobalization is the shift in the China-US relationship from cooperation to competition,

[8] Please refer to *The Rise of China's Innovation Economy* written by CICC Research and CICC Global Institute.

accompanied by a rise in geopolitical risks. To control efficiency losses from deglobalization, China and the US can first ensure that competition takes place in an orderly manner.

Orderly competition between China and the US at the economic level means that the two countries need to maintain a bottom line in their economic and trade relations. Where should this bottom line be? The latest round of globalization essentially adds MNCs and accompanying FDI as well as information flows on top of traditional international trade relations. The bottom line of deglobalization should be to maintain normal international trade. With China-US decoupling, MNCs would re-distribute their FDI according to the principles of efficiency revealed by economic geography and comparative advantage theories, and global industry chains would be re-configured under respective security concerns of China and the US. This is bound to have an impact on global trade. However, trade in manufactured goods between China and the US and between the two countries and third-party countries should not be cut off or reduced on a large scale. Global trade should not be fundamentally affected.

Orderly competition between China and the US at the level of international economic and trade order means a retreat from the WTO's full and universal free trade to preferential bilateral trade agreements and regional trade agreements, but not uncontrolled trade frictions (see Chapter 4 for details). China and the US can leverage their economic influence and compete economically on a global scale, but they should not disrupt normal economic activities with each other's economic and trade partners. In this way, economic competition between the two countries could be conducive, rather than detrimental, to the economic development of other countries in the world.

On the one hand, the US can certainly promote manufacturing reshoring and friendshoring to meet its global industry chain security needs. On the other hand, China can certainly promote manufacturing innovation and upgrading through industrial policies to enhance its industrial competitiveness and independence in order to meet its industry chain security needs. However, for both countries, the pursuit of security will likely lead to a loss of efficiency. Both countries should not pursue industry chain security at any cost. Both countries need to assess the optimal extent to which security can be pursued in light of the efficiency loss in practice, and strike a balance between security and efficiency.

Controlling the loss of efficiency is particularly important for China, which still lags far behind the US in terms of economic efficiency. Although China has made substantial progress compared to 40 years ago, China's GDP per capita is still only about one-fifth that of the US as of 2021. Security concerns can only be addressed through technological progress, which in turn is part of economic growth. Therefore, security concerns ultimately have to be addressed through economic development, which requires emphasis on efficiency. For China, security and efficiency are more unified, and it is more necessary for the country to maintain its strategic focus. In the face of the changing geopolitical landscape, China could adhere to peaceful

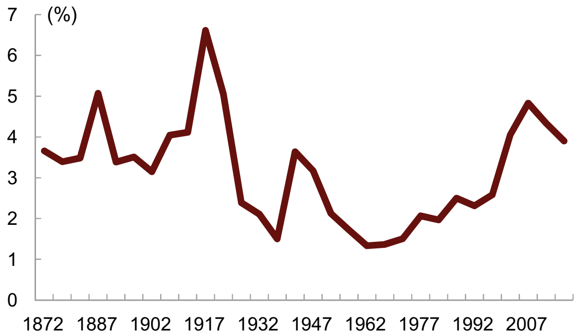

Fig. 2.6 Industrial countries' ratio of current account surplus to GDP. *Note* The 15 countries are Argentina, Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, the UK, and the US. *Source* Obstfeld, Maurice, and Alan M. Taylor. Global capital markets: integration, crisis, and growth. Cambridge university press, 2004. Our World in Data, CICC Global Institute

development, and continue to strengthen the foundation of economic development and technological progress to ensure that its economy continues to grow along the trend line. Fundamentally, efficiency could be considered in the pursuit of security; if security is pursued regardless of cost, both efficiency and security could be lost.

Chapter 3
New Advantages in Economies of Scale Amid Deglobalization

Abstract Economies of scale refer to the phenomenon in which market agents (i.e., firms) at the microeconomic level increase economic benefits by expanding the scale of production, as evidenced by the decrease in average total cost due to increased output. Applying this to the macro level, a country's population or market scale expansion will drive more sophisticated division of labor and transactions, thereby improving economic efficiency.

According to the theory of economies of scale, large countries could undergo stronger industrial development and faster economic growth and achieve greater wealth than small countries. However, insufficient emphasis has been placed on scale in existing macroeconomic analysis, in our view, and the reality is that many small economies are wealthier than large ones. During the era of globalization over the past few decades, some small countries enjoyed economies of scale brought by the global markets through their participation in division of labor and cooperation in global industry chains.

In the era of deglobalization, however, small countries' ability to participate in the global division of labor and to enjoy economies of scale at a global level becomes limited. Instead, the importance of statehood in political terms has increased, and large countries can accumulate stronger competitive advantages by leveraging their large scale. In addition, the development of the knowledge economy, especially the digital economy, amplifies the scale advantages enjoyed by large countries, in our opinion.

China is one of the biggest countries in the world in terms of population and economy, which we believe lays a foundation for it to leverage scale advantages under new circumstances. Developing a market economy and promoting internal market competition are key to translating large scale into economic growth, in our view, which requires an expansion of domestic consumption and development of a unified domestic market. We believe attention could be paid to address the market failure caused by distortions such as externalities (a cost or benefit caused by a producer but not borne by that producer) and monopolies and in particular, to improve governance mechanisms for real estate, finance, and the digital economy.

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Against the background of deglobalization, scale advantages both provide a new source of economic growth for large countries and lay a foundation for cross-border cooperation. Large countries enjoy advantages in the new landscape of division of labor in global industry chains thanks to their larger industrial systems and tighter integration among different parts of their industry chains. Leveraging its domestic industrial system, China can strengthen industry chain integration with other countries, facilitate in-depth cross-border cooperation, and improve industrial efficiency and security, in our opinion.

Keywords Economies of scale · Scale advantages · Deglobalization · Cross-border industry chains

3.1 Economies of Scale Could Become an Important Source of Economic Growth in China

Demographic dividend and globalization, two important historical drivers of China's rapid economic growth, are gradually diminishing, underscoring the importance of promoting high-quality development. Since 1978, the demographic dividend[1] and integration into the global market have helped China achieve average annual GDP growth of 9.3%[2] up to 2022, and rapidly catch up with developed economies such as the US and Japan. However, we believe China could shift towards an economic development model that relies more on total factor productivity as the number of working-age people declines, the savings rate trends lower, and capital accumulation slows due to the aging population (Fig. 3.1). At present, China's economy is undergoing a shift in growth rate, indicating strong demand for development. As stated in the report to the 20th CPC National Congress, development is the top priority, and efforts should be made to accelerate the creation of a new, high-quality development model.[3] Therefore, whether scale advantages can facilitate high-quality development is the primary issue we discuss in this chapter.

The role of economies of scale in driving economic development deserves more attention. Economists argue that labor and capital investment may reach bottlenecks, and improvement in total factor productivity is the fundamental driving force for long-term economic development.[4] In that sense, economies of scale plays a

[1] As defined by United Nations Population Fund, the demographic dividend is "the economic growth potential that can result from shifts in a population's age structure, mainly when the share of the working-age population (15–64) is larger than the non-working-age share of the population (14 and younger, and 65 and older)".

[2] Source: World Bank.

[3] *Xi Jinping: Hold High the Great Banner of Socialism with Chinese Characteristics and Strive in Unity to Build a Modern Socialist Country in All Respects: The Report to the 20th National Congress of the Communist Party of China*, released by Xinhuanet on October 25, 2022.

[4] Solow, Robert M. "A contribution to the theory of economic growth." *The quarterly journal of economics* 70.1 (1956): 65–94.

clear role in facilitating total factor productivity growth. Specifically, by promoting people's well-rounded development, building sound industry chains, and encouraging sci-tech innovation, economies can achieve higher output with the same input, among others, which is reflected in economies of scale from a static perspective. When economies of scale continue to play a role, it can be manifested in the realization of long-term development with increasing total output. At present, a prominent feature of China's economy is its fairly large size. China has long been the most populous country in the world, and its GDP was equivalent to 70.3% of that of the US in 2020.[5] We believe that if China leverages its large population and domestic economy to fully unleash its potential economies of scale, it will better drive its economic development.

Large countries enjoy greater scale advantages against the background of deglobalization. The contribution of large countries' greater scale to economic growth has been underemphasized in existing macroeconomic analysis, in our view, in part because a large number of small economies have achieved swift economic growth over the past few decades and grew rapidly into wealthy economies. To understand this contradiction, we focus our analysis on the role of globalization. In the era of globalization and free trade after the Second World War, small economies successfully integrated into the global economic system, expanded the size of their potential market, and benefited from global economies of scale. In extreme cases, small economies can still enjoy economies of scale through international trade, even when their domestic demand is limited. Deglobalization has led to frictions among various countries in international markets. In response, countries need to rely more on the scale of their domestic markets, and then participate in international competition. In such a context, large countries show stronger economies of scale than small countries, backed by their large populations and economies, and exhibit more obvious scale advantages.

Deglobalization drives China to shift to a growth model that relies more on scale advantages. Against the background of geopolitical conflicts and intensifying technological competition, the trend of deglobalization has become increasingly visible and the division of labor in global industry chains has slowed or even shown signs of a reversal.[6] As the previous model of international division of labor faces challenges, China's historical paths to improving economic efficiency could face obstacles, including the export model that relies heavily on external demand and comparative advantages as well as learning-by-exporting. On the contrary, the domestic market has become more decisive to technological progress, economic growth, and trade patterns. Therefore, the scale advantages as a large country may play a more important role in driving China's economic growth.

Against the backdrop of competition among major countries, China could rely more on scale advantages to develop a knowledge economy. Besides deglobalization, another new trend worthy of attention is the boom of the knowledge economy,

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[5] Source: World Bank.

[6] James, Harold. "Deglobalization: The rise of disembedded unilateralism." *Annual Review of Financial Economics* 10 (2018): 219–237.

especially the digital economy. Compared with the traditional economy, the knowledge economy is characterized by its stronger non-rivalrous nature and economies of scale. Therefore, the original scale of a company or industry often determines the level of its competitiveness in the future. In addition, large countries can successfully support the sizable initial investment needed in the development of the knowledge economy and the large scale of subsequent innovation on multiple fronts, thus exhibiting competitive edges in this regard. In other words, the domestic markets of large countries play the role of "initial incubators", which can more rapidly cultivate mature knowledge-based products and quickly seize share of the international markets. For example, China and the US have become home to a large number of internet giants, while European companies may lag behind in global competition. However, this also means that governments are more inclined to support domestic companies internally and adopt market segmentation and trade protectionism externally. Against the background of competition among large countries, China could rely more on its scale advantages to secure a favorable environment for the development of the knowledge economy in the face of the abovementioned competitive pressures from other countries, in our opinion.

In summary, we believe China is characterized by strong demand for development, a large population, and a large economy. **Scale advantages will likely replace demographic dividend and globalization to become an important source of China's economic growth against the background of deglobalization and development of the knowledge economy.**

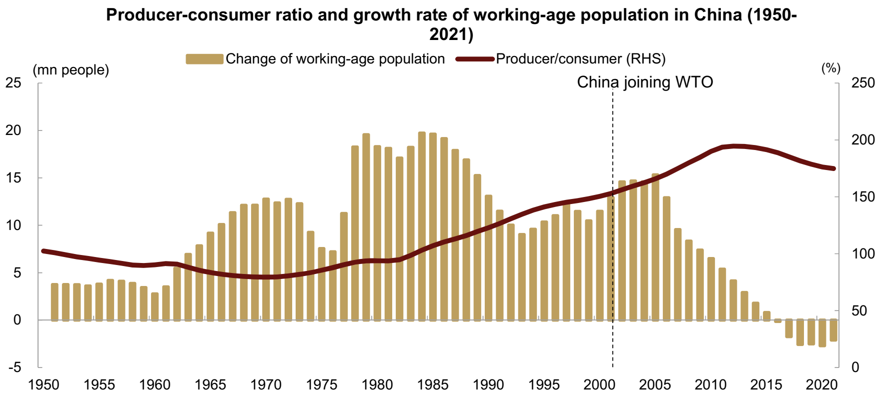

Fig. 3.1 China's demographic dividend is diminishing. *Note* Producer here is defined as the population aged 20–64; consumer is defined as the population aged below 20 and above 64. *Source* Population Division of United Nations Department of Economic and Social Affairs, CICC Global Institute

3.2 Theoretical Origins and Functions of Large Countries' Scale Advantages

3.2.1 Economies of Scale and Scope Together Constitute Large Countries' Scale Advantages

Population and market scale facilitate division of labor and bring economies of scale on the industrial side. Early economic theories tend to explore the sources of economies of scale from the production side—e.g., how scale promotes division of labor and forms thereof. Known as the founder of modern economics, Adam Smith believed that population growth leads to specialized division of labor, which improves productive powers of labor and drives an increase in returns to scale in the overall economy.[7] Alfred Marshall made a distinction between "internal" division of labor within individual enterprises and "external" development of the industry.[8] The latter stems from industrial development driven by the growth of the working population. Thus, firms can improve the efficiency of production by sharing skilled labor and other infrastructure, resulting in external economies of scale. On this basis, Allyn Young noted that the expansion of the market demand will also lead to new forms of division of labor among industries, including roundabout methods of production[9] and the rise of the intermediate goods sector to further improve economic efficiency.[10] Backed by Young's theory, the demand side also started to attract attention as one of the sources of economies of scale.

Mutually reinforcing demand and supply and concentration of production factors and industrial agglomeration strengthen economies of scale. The new economic geography theory takes multiple sources of economies of scale into consideration, and believes that concentration of production factors and industrial agglomeration within a certain geographical area could enhance economies of scale. First, industrial development tends to take place near large markets, and producers of final goods and intermediate goods are generally attracted to larger consumer markets and clusters of final goods producers due to transportation cost considerations (i.e., backward linkages). Second, producers of final goods are attracted to clusters of intermediate goods producers and to regions with better industrial development (i.e., forward linkages). These two effects work together and reinforce each other, driving factors and industries to concentrate in specific regions and increasing returns to scale. Third, the positive externalities of industrial development enhance economies of scale as industries concentrate in specific regions, allowing firms to share infrastructure and improve division of labor among industries. Fourth, transportation costs

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[7] Smith, Adam. *The wealth of nations* [1776]. Vol. 11937. na, 1937.

[8] Marshall, Alfred. *Principles of economics: unabridged eighth edition.* Cosimo, Inc., 2009.

[9] Roundabout method of production refers to the production method of manufacturing capital goods first and then producing consumer goods.

[10] Youno, Allyn A. "Increasing returns and economic progress." *The economic journal* 38.152 (1928): 527–542.

support concentration of production factors and push up the income level of clusters. That helps advantageous regions build larger local markets with strong demand, which in turn further reinforces economies of scale.

Economies of scope are another important source of scale advantages enjoyed by large economies. Economies of scope refer to the improvement in efficiency brought by increase in variety of products rather than quantity—i.e., the cost of producing multiple products together is lower than producing each product separately. Specifically, vertical integration strategies, product diversification strategies, and sharing of sales and R&D channels at the corporate and industry levels could all create economies of scope.[11] As small economies face restrictions from their small populations and market scale, their industrial development tends to focus on specific areas and is highly dependent on overseas markets. Therefore, small economies are in a disadvantageous position in achieving economies of scope, making it difficult for them to gain scale advantages. In contrast, large countries, by leveraging their sizable domestic markets, are better positioned to facilitate production diversification and make full use of domestic resources and technologies to create new products and services. Thus, large countries generally outperform in industry diversification and specialization of labor. In addition, economies of scale and economies of scope could be mutually reinforcing, but only under the prerequisite of a sufficiently large market and a vertically integrated industry chain, in our opinion. Therefore, large countries are better positioned to achieve economies of scope than small countries, in our view, which constitutes an additional source of scale advantages for large countries.

3.2.2 Large Countries' Scale Advantages are Conducive to Industrial Development and Economic Growth

Large countries provide room for more intense competition and innovation, which is conducive to cultivating larger and more competitive firms.[12] First, the scale advantage of large countries provides ample room for a larger number of companies and products, which can facilitate market competition and drive firms to lower the markup ratio. With lower markups, firms must sell more goods to break even, leading to an increase in firm size.[13] Assuming economic equilibrium, large countries can cultivate larger and more competitive companies backed by their sizable domestic markets. Second, as such companies leverage large countries' scale advantages to amortize their fixed R&D costs over a greater number of goods, they find

[11] Sakhartov, Arkadiy V. "Economies of scope, resource relatedness, and the dynamics of corporate diversification." *Strategic Management Journal* 38.11 (2017): 2168–2188.

[12] Desmet, Klaus, and Stephen L. Parente. "Bigger is better: market size, demand elasticity, and innovation." *International Economic Review* 51.2 (2010): 319–333.

[13] Campbell, Jeffrey R., and Hugo A. Hopenhayn. "Market size matters." *The Journal of Industrial Economics* 53.1 (2005): 1–25.

it profitable to adopt more advanced technologies, thus supporting innovation on multiple fronts.[14]

Large market scale expands room for innovation, driving development and upgrading of domestic industries. Innovation activities fall into two categories—i.e., those requiring large initial investment with strong economies of scale, and those requiring relatively small initial investment and creating less strong economies of scale.[15] Firms in large countries are characterized by their greater size and ability to make significant initial investments, thus showing competitive advantages in innovation activities with strong economies of scale. In contrast, firms in small countries generally participate in innovation activities with limited economies of scale. However, they might face fiercer cost competition as firms in large countries can also participate in such innovation activities. This means that large countries' scale advantages may help them both expand corporate innovation and stimulate industrial development. In other words, we believe large countries are in a better position to gain dominance in high-end technological industries with stronger returns to scale as they excel in both types of innovation activities.

The new growth theory holds that large countries' scale advantage could boost economic growth. The traditional theory holds that economic growth is independent of scale as it assumes that countries have the same level of exogenous technological capability and small countries can actually grow faster. This conclusion can explain, in part, the convergence of growth across countries in the era of globalization after the Second World War, but not the fact that some countries have posted stagnant growth while the US has long maintained leadership in economic growth. Unlike neoclassical economics, the new growth theory that emerged in the 1980s holds that technological progress comes from learning by doing,[16] or human capital accumulation and R&D inputs.[17] Therefore, as large countries support mass production, human capital accumulation, and R&D inputs, they may witness faster technological progress and economic growth. Of note, as technologies have strong spillover effects within a country, allowing different industries to adopt new technologies as soon as they are developed, large countries also enjoy additional economies of scale, underpinning their economic growth. Driven by these factors, large countries can achieve faster economic growth by leveraging their scale advantages, in our opinion.

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14 Argente, David, et al. "Patents to products: Product innovation and firm dynamics." (2020).

15 Fagerberg, Jan, and Morten Fosaas. "Innovation and innovation policy in the Nordic region." (2014).

16 Romer, Paul M. "Growth based on increasing returns due to specialization." *The American Economic Review* 77.2 (1987): 56–62.

17 Lucas Jr, Robert E. "On the mechanics of economic development." *Journal of monetary economics* 22.1 (1988): 3–42.

3.2.3 *Large Scale Helps Large Countries Gain Dominance in Cross-Border Industry Chains*

Traditional trade theory neglects the importance of scale. Regarding international trade models, the traditional theory of comparative advantage holds that a country will import a product if it has higher demand for that product compare to other products. This theory holds that the fundamental driving force of trade stems from differences in production among countries (i.e., comparative advantage). Moreover, if there is a diminishing return to scale on the production side, production activities seeking to address a country's higher domestic demand should be allocated to multiple countries. As a result, a country would increase imports of the product and the gap among countries in terms of demand is narrowed via the production side.

The new economic geography theory emphasizes that sizable domestic demand market will result in a home market effect,[18] **which has a decisive impact on international trade patterns.** For industries with increasing returns to scale, large countries enjoy stronger economies of scale thanks to their larger population and economies, which manifests itself as the home market effect on the export side. Specifically, leveraging the large market with stronger demand, domestic companies have accumulated initial scale advantages, with their products featuring lower production costs and higher quality. As a result, domestic companies gain competitive advantages in the international markets and quickly seize market share, as evidenced by increased exports of such products from the domestic market and strengthened scale advantages by marketing the products in the global markets. In other words, strong home market demand drives the production side via increasing returns to scale, and the country increases production and exports of the product. In extreme cases, some economists[19] even believe international trade is nothing but an extension across national frontiers of a country's own web of economic activity. In this process, the scale of domestic demand is a key factor triggering home market effects, which means large countries should attach greater importance to their scale advantages on the demand side.

Large countries are more likely to have home market effects in industries with high levels of product differentiation and complexity. According to the experiences of OECD countries—e.g., the radar communication and automobile manufacturing industries in these countries—home market effects do exist.[20] Specifically, at the country level, home market effects are more important for very large and very

[18] The home-market effect illustrates the idea that "countries with larger demand for some products at home tend to have larger sales of the same products abroad". Cited from Costinot, Arnaud, et al. "The more we die, the more we sell? a simple test of the home-market effect." *The quarterly journal of economics* 134.2 (2019): 843–894.

[19] Linder, Staffan Burenstam. *An essay on trade and transformation.* Stockholm: Almqvist & Wiksell, 1961.

[20] Head, Keith, and Thierry Mayer. "The empirics of agglomeration and trade." *Handbook of regional and urban economics.* Vol. 4. Elsevier, 2004. 2609–2669.

small countries.[21] This reflects very large economies' sizable domestic markets and very small economies' success in leveraging economies of scale during the globalization process over the past few decades (by focusing on specific industries and integrating themselves into global industry chains). At the industry level, industries with greater transport costs and higher levels of product differentiation and complexity also have stronger home market effects.[22] Such industries tend to require a larger initial investment, and a bigger domestic market can support the large initial investment needed and trigger subsequent stronger economies of scale. For example, due to aging populations and households' stronger purchasing power, domestic pharmaceutical markets in developed countries usually exhibit strong demand, which provides the impetus for innovation and R&D spending in the pharmaceutical industry.[23] The home market effects help these countries gain a greater competitive advantage in the export of pharmaceuticals.[24]

Scale advantages help large countries focus their industries and export sectors on high-quality, high-value-added, and high-end technological products. Home market effects can boost domestic industries and further strengthen the scale advantages of large countries, boding well for their economic and industrial development. On the one hand, scale advantages increase the income level of domestic consumers in large countries and drive them to shift to products of higher quality and high-end technological products.[25] Improvement on the demand side could drive upgrading of domestic industries and export sectors, and encourage producers and exporters to invest more in sci-tech innovation.[26] On the other hand, bigger countries have larger domestic markets and an increased number of larger-sized companies that can afford higher initial investments. Thus, they are better positioned to develop industries with a high degree of increasing returns to scale. As a result, we believe small countries can only export products with medium returns to scale, while large countries are more likely to develop and export products with high returns to scale.[27] Overall, the development paths of different countries could diverge going forward and show a core-periphery structure due to home market effects. Large countries could maintain competitive advantages in industrial and economic development leveraging their sizable domestic markets.

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[21] Crozet, Matthieu, and Federico Trionfetti. "Trade costs and the home market effect." *Journal of International Economics* 76.2 (2008): 309–321.

[22] Hanson, Gordon H., and Chong Xiang. "The home-market effect and bilateral trade patterns." *American Economic Review* 94.4 (2004): 1108–1129.

[23] Acemoglu, Daron, and Joshua Linn. "Market size in innovation: theory and evidence from the pharmaceutical industry." *The Quarterly journal of economics* 119.3 (2004): 1049–1090.

[24] Costinot, Arnaud, et al. "The more we die, the more we sell? a simple test of the home-market effect." *The quarterly journal of economics* 134.2 (2019): 843–894.

[25] Redding, Stephen, and Anthony J. Venables. "Economic geography and international inequality." *Journal of international Economics* 62.1 (2004): 53–82.

[26] Melitz, Marc J., and Gianmarco IP Ottaviano. "Market size, trade, and productivity." *The review of economic studies* 75.1 (2008): 295–316.

[27] Holmes, Thomas J., and John J. Stevens. "Does home market size matter for the pattern of trade?." *Journal of International Economics* 65.2 (2005): 489–505.

Large countries play a dominant role in the division of labor in global industry chains. Leveraging the large size of their domestic markets, large countries have a stronger ability to drive the development of their domestic industries, which has far-reaching implications for the development of division of labor in global industry chains. Economists Antonella Nocco et al. (2019)[28] believes that in a global welfare perspective, optimal multilateral trade policy should promote sales of low cost firms to all countries, trim sales of high cost firms to all countries, and reduce the entry of firms in all countries, especially in disadvantaged ones (countries with smaller domestic market scale, worse state of technology in terms of higher innovation and production costs, and worse geography in terms of closer proximity to other countries). Specifically, reducing the entry of firms means promoting the integration of cross-border industry chains while advancing sales of low cost firms means industry chain integration is premised on intensifying competition and driving out inefficient companies, which can help increase overall economies of scale. More importantly, scale advantages can reduce dependence of countries with larger domestic industrial capacity on other countries, while increasing other countries' reliance on them.[29] Thus, large countries play a dominant role in organization of and participation in global industry chains, as evidenced by the integration of small countries into industry chains dominated by large countries. In particular, we believe small countries could be integrated into industry chains dominated by large countries to a greater extent due to lower trade costs and similar demand preference with large neighboring countries.

3.3 Status Quo of and Issues With Economies of Scale in China

3.3.1 China Has the Foundation for Leveraging Scale Advantages

China has the potential to leverage scale advantages backed by its large population and economy. China has long been one of the world's most populous countries with a population of 1.41bn in 2022, and its population is much larger than that of the US (Fig. 3.2). China's potential for scale advantages is also reflected in its large economy. In 2022, China's GDP at current prices reached US$17.96trn, ranking No.2 in the world. In terms of purchasing power parity (PPP), China's GDP reached Int$30.34trn in 2022, ranking No.1 in the world and nearly three times that

[28] Nocco, Antonella, Gianmarco IP Ottaviano, and Matteo Salto. "Geography, competition, and optimal multilateral trade policy." *Journal of International Economics* 120 (2019): 145–161.

[29] Fernandes, Ana Margarida, Hiau Looi Kee, and Deborah Winkler. "Determinants of global value chain participation: Cross-country evidence." *The World Bank Economic Review* 36.2 (2022): 329–360.

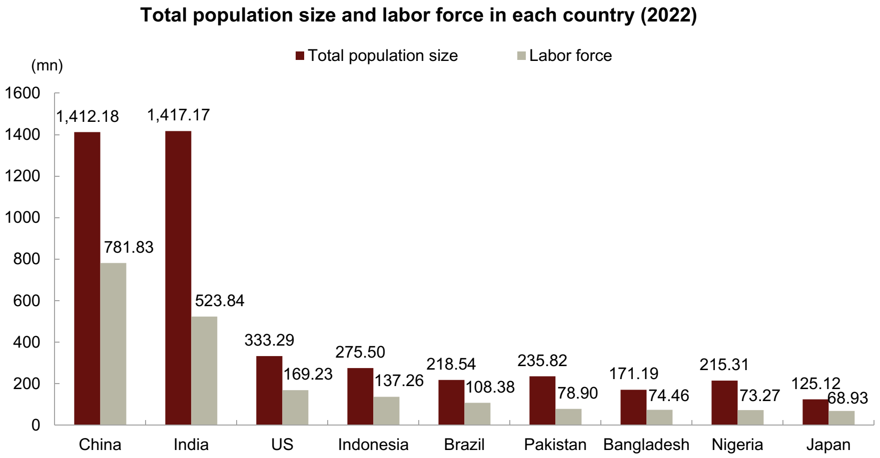

Fig. 3.2 China's population size and labor force have been among the top of the world. *Source* World Bank, CICC Global Institute

of India (Int$11.90trn).[30] China has a large number of potential consumers and the world's largest GDP in PPP terms as of 2022, which also provide strong support for consumption in China. In addition, a higher total GDP also means stronger industrial development and more job opportunities in China, in our view, laying an important foundation for China to leverage its competitive advantages in total working population on the industrial side.

China shows even greater potential for sale advantages from the perspective of labor force. China's population aged 15–64 totaled 984 mn in 2022, only 2.4% higher than 961 mn in India.[31] However, China's labor force (working-age population * labor force participation rate) reached 782 mn, 49.2% higher than 524 mn in India, and largely equal to India, the US, and Pakistan combined (Fig. 3.2). China's labor force is much larger than those in other countries, mainly because women generally enjoy job opportunities in China, and the country can provide sufficient jobs for its large working-age population backed by its larger economy and better-developed industries. Although China's labor force participation rate has declined in recent years, it still equaled 68.1% in 2021, much higher than 41.6% in India.[32] In general, China shows good potential for scale advantage in terms of labor force.

We believe China currently has a window of opportunity to leverage its scale advantages as a large country. According to the Population Division of the United Nations Department of Economic and Social Affairs, China's population may decline over the next 20–30 years. In addition, a decline in total population is usually accompanied by population aging, which would add to the pressure on China's economic growth. As a result, we believe that in addition to encouraging childbearing and

[30] Source: World Bank.

[31] Source: Population Division, Department of Economic and Social Affairs, United Nations.

[32] Source: Population Division, Department of Economic and Social Affairs, United Nations.

raising the birth rate, China could also seize the important window of opportunity when it stands at a leading position in terms of population and labor force as well as the GDP around the world to leverage its scale advantages so as to offset the drag from shrinking demographic dividend and declining population on industrial and economic development.

3.3.2 China's Export Sector Shows Economies of Scale

From the perspective of international trade, China has initially shown scale advantages. Since 2000, China has gradually become one of the centers of division of labor in global manufacturing and industry chains, accounting for 27.3% of the global manufacturing output in 2018.[33] Backed by the large scale of China's domestic market and industries, 24 out of the 26 manufacturing industries in China have home market effects,[34] including chemicals, communications and electronics, transportation equipment, and machinery manufacturing. By industry, capital-intensive industries have the strongest home market effects, followed by technology-intensive industries, while resource-intensive and labor-intensive industries do not have home market effects.[35] As we previously mentioned, home market effects are more likely to exist in industries with large initial investment and high degrees of increasing returns to scale, which tend to be characteristics of capital-intensive and technology-intensive industries. In terms of export destinations, China's exports to Southeast Asia and Central Asia have stronger home market effects,[36] partly because of their geographical proximity and similar product preferences to China. Therefore, products designed and produced based on China's domestic demand could easily be marketed to these regions, in our view. On the contrary, China's exports to other developing countries do not have strong home market effects, in our opinion.

The rise of China's PV industry demonstrates the importance of home market effects. China has an enormous domestic market with strong photovoltaics (PV) demand—the country's cumulative installed PV capacity reached 205MWh in 2019, accounting for 32.6% of the global total and far exceeding those of other countries (i.e., the US and Japan).[37] Leveraging the abundant supply of raw materials and strong market demand, Chinese PV companies accumulated scale advantages. Internally,

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[33] Baldwin R, Freeman R. Risks and global supply chains: What we know and what we need to know. National Bureau of Economic Research, 2021.

[34] CHEN Wen, and LI Jialu. "A Study on the Home Market Effects of China's Manufacturing Exports: An Empirical Analysis Based on the Gravity Model." *World Economy Study* 2(2012):6.

[35] SHE Qunzhi, and HU Huayu. "Retesting the local market effect of China's manufacturing industry: A perspective of value-added trade." *Journal of Zhongnan University of Economics and Law* 000.003(2021):79–90.

[36] HUANG Zhihua, HE Yi. "A Study on Local Market Effects in China and 34 BRI Countries Based on Gravity Models." *China Soft Science* 3(2020):100.

[37] Kratz, Agatha. "Home advantage: how China's protected market threatens Europe's economic power." (2021).

Chinese companies feature a higher degree of automation and have worked to accelerate product standardization and streamline production processes, helping them reduce production costs. Externally, specialized clusters of producers and suppliers have been developed in China's PV industry, enabling domestic PV producers to obtain key inputs more easily and further improve their production efficiency. As a result, China has cultivated a highly competitive PV industry with a share of nearly 100% in the domestic market in 2021.[38] Generally speaking, the average size of Chinese PV companies is four times that of their US counterparts, helping them cut production costs and capture market share in Europe and even the global market. In 2019, China's PV industry gained a 76% share of the global market thanks to its competitive advantages backed by strong local market demand.[39]

3.3.3 China's Scale Advantages Have Not Been Fully Exploited

On the demand side, China's sizable domestic consumer market still needs to be further cultivated. China had ranked No.1 in the world in terms of total population before 2022, and ranked No.1 in terms of GDP (at constant PPP prices in 2017), indicating that the country has a large number of potential consumers and strongest potential purchasing power in the world. However, it ranks No.3 in the world in terms of the share of total global private sector consumption in 2020, following the US and the EU. In addition, the share of other countries in the world's total private sector consumption is usually higher than their share of the world's total GDP or population, while the situation is the opposite in China, indicating that it has yet to fully translate its scale advantages in terms of total population and GDP into consumption,[40] in our opinion. From a structural point of view, compared with fast-moving consumer goods (FMCG) and discretionary consumer goods, China's luxury consumption outshines in terms of share of the world's total and pace of growth.[41] In 2019, China was the world's largest luxury goods market with a share of 33%.[42] As we pointed out in our book, *Building an Olive-shaped Society*,[43] China's Gini coefficient declined steadily over the past decade, but it was 0.47 in 2020, still higher than the international warning level of 0.4. Consumption divergence caused by the income gap reduces the homogeneity of demand in China's domestic market and

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[38] Source: International Energy Agency (IEA).

[39] Source: ECFR.

[40] Source: World Bank.

[41] McKinsey & Company. Five consumer trends shaping the next decade of growth in China. November 11, 2021.

[42] BCG, Tencent. Digital Luxury Report. 2020.

[43] CICC Research, CICC Global Institute. *Building an Olive-shaped Society*. CITIC Press, June 2022.

is not conducive to the development of scale advantages as a large country on the demand side, in our opinion.

On the industrial side, China's scale advantages have not been fully reflected in high-end technological products. According to Harvard University's Economic Complexity Index (ECI), China ranked 18th in the world in 2021, up six places in the past decade.[44] However, at the product level, China only accounted for 13.0% and 0.4% of the world's net exports of products with a Product Complexity Index (PCI) greater than 1.3 or 1.8, well below Germany's 19.5% and 5.2%, and Japan's 21.6% and 11.6%. More notably, although China's share of the world's total net exports of products with PCI greater than 1.3 is much higher than the US's 4.9%, its share of net exports of products with PCI greater than 1.8 equals only one-sixth that of the US (2.3%).[45] This both highlights the risk to China's access to key technologies, and indicates that China has not fully leveraged its scale advantages in driving corporate and industrial upgrading and the transition towards high-end technological industries, in our opinion.[46]

For example, China's high-end equipment sector is still characterized by an emphasis on complete equipment rather than parts and components, as well as a lack of mid-range and high-end equipment. As discussed in Chapter 11, China's high-end equipment industry focuses on the R&D of complete equipment but attaches insufficient importance to core parts and components from our point of view, resulting in a relatively low share of domestically manufactured core components in the domestic market. Specifically, despite of China's large demand for industrial robots, Japan enjoys a dominant position in both core components such as controllers and reducers in the upstream, as well as large-scale industrialization and system integration in the midstream and downstream. In addition, on account of strong demand underpinned by domestic real estate and infrastructure investment, China's excavator industry has developed advanced processes and witnessed rapid growth, and Chinese manufacturers have become world-leading in some market segments. However, in the field of industrial lathes in which trial and error costs are relatively high, the strong demand from domestic manufacturing industries has not been successfully converted into robust growth momentum of related industries.

The status quo of China's high-end equipment industry shows that China has yet to fully leverage the large size of its domestic market to facilitate the division of labor among industries, improve integration among different parts of industry chains, and increase the supply of core components. In particular, we believe increased effort is needed to leverage scale advantages to help domestic industries shift to higher-end technological products with stronger economies of scale.

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[44] Source: Harvard ATLAS 7.0.

[45] Source: Harvard ATLAS 7.0.

[46] For a more detailed discussion of technological innovation, see CICC Research, CICC Global Institute. *The Rise of China's Innovation Economy*. CITIC Press, March 2022.

3.3.4 Factors Constraining China From Leveraging Scale Advantages

As mentioned previously, China's enormous domestic consumer market still has room for improvement, and the positive impact of scale advantages on China's industrial development has not been fully reflected. The reason is that externalities and monopoly, the two potential defects of the market system, have been two obstacles hindering China from effectively transforming its large scale into competitive advantages, in our opinion. Specifically, we believe income gaps, the drag from land sectors,[47] and a monopoly caused by integration of financial and industrial businesses are three domestic constraints that need to be addressed to better leverage scale advantages.

Income gap is not conducive to the formation of a market with strong demand. Large countries have sizable populations and economic prowess, which lay a basis for advancing mass production and leveraging economies of scale to facilitate industrial and economic development. However, prerequisites exist for large countries to leverage their scale advantages. Specifically, only when income generated by the leading sectors benefit most people and consumer demand is relatively homogeneous can the consumer buying power of a large country be effectively translated into strong market demand for domestically manufactured goods, which we believe is key to triggering economies of scale.[48] On the contrary, the experience of countries such as the UK shows that the wealth gap has led the country's affluent class to buy imported luxury goods. In this case, the gains from economic development could not be absorbed by the domestic industrial sector, making it nearly impossible for the UK to leverage scale advantages as a large country. As mentioned earlier, China still faces problems such as consumption divergence and insufficient translation of gains from economic growth into consumption.[49] Looking ahead, greater attention is needed regarding equitable income distribution, in our view, so as to lay a foundation for leveraging scale advantages on the demand side.

Land sectors squeeze other industries as a natural monopoly, leading to diseconomies of scale. First, compared with other industries, labor productivity growth in industries closely related to land (i.e., the construction industry) is usually slower, which may hinder the improvement in overall productivity and transition towards high-tech industries. Labor productivity in the construction sector rose only 21% over 1995–2014, lower than the 70% growth in overall productivity and the 97% growth in productivity of the manufacturing sector over the same period.[50] In addition, we believe the uneven distribution of land ownership leads to a widening income gap, which results in insufficient demand for domestic manufacturing industries and a

[47] Land sectors here refer to industries that are land-related, such as real estate, construction, etc.

[48] Murphy, Kevin M., Andrei Shleifer, and Robert Vishny. "Income distribution, market size, and industrialization." *The Quarterly Journal of Economics* 104.3 (1989): 537–564.

[49] For a more detailed discussion on the issue of income distribution, please refer to the book: CICC Research, CICC Global Institute. *Building an Olive-shaped Society*. CITIC Press, June 2022.

[50] Source: GGCD-10, OECD, WIOD, World Bank.

shift to a non-technology-intensive development path, becoming a drag on growth. At the macro level, such a process manifests itself as land sectors squeeze benefits from economic development and cause negative externalities to the development of other industries.[51]

Second, spending on plants, machinery, and equipment, and on R&D can be shared as scale expands, and the spreading of fixed costs drives unit costs down. However, when expanding the use of land, investment in infrastructure (such as roads and hydropower facilities, etc.) must increase proportionately, making it difficult for fixed costs to be shared. Such a characteristic suggests that land could be the "shortest board" in scale expansion, which we believe may lead to price premiums and monopoly. Therefore, land sectors themselves are also characterized by diseconomies of scale. China's real estate industry has experienced rapid growth over the past decade, and is one of the areas that we believe merits special attention as China works to leverage its scale advantages as a large country.

The integration of financial and industrial businesses undermines competitive fairness and impairs economies of scale. With the integration of financial and industrial businesses, financial groups hold controlling stakes in both financial institutions and real-economy companies, and extend the government's credit guarantees for them to real economy sectors. Such real-economy companies can more easily win over competitors and gain market share. Furthermore, with the help of low-cost funds backed by the government's credit guarantees, some inefficient real-economy companies can survive or even thrive for a long period of time. The non-competitive nature of their monopolies leads to stronger crowding-out effects on domestic industries and scale advantages. For example, the integration of financial and industrial businesses caused by excessive global financialization in the past few decades has reduced overall economic efficiency and led to diseconomies of scale.[52] In China, the "blind expansion" of a small number of companies to the financial sector has led to continuous accumulation of risks and problems.[53] To fundamentally address the non-competitive monopoly caused by the integration of financial and industrial businesses, we believe the key is to restrict the government's credit guarantees for financial institutions from extending to real-economy industries, and advance the separation of the financial sector from industrial sectors and separation of various financial sub-sectors from each other, which is in fact a fundamental principle to which the US has adhered since enactment of financial regulatory reform via the Glass-Steagall Act in 1933.[54]

[51] PENG Wensheng. *Fading Dividend—Seeking New Balance in China.* Social Science Academic Press, 2013.

[52] Pogach, Jonathan, and Haluk Unal. "The dark-side of banks' nonbank business: Internal dividends in bank holding companies." *FDIC Center for Financial Research Paper* 2018-01 (2019).

[53] Financial Stability Analysis Group of the People's Bank of China. *China Financial Stability Report 2020*. China Financial Publishing House, 2020.

[54] Omarova, Saule T. "Beyond Finance: Permissible Commercial Activities of US Financial Holding Companies." *An Unfinished Mission: Making Wall Street Work for Us, A Report by Americans for Financial Reform & the Roosevelt Institute (2013)* (2013): 110–125.

3.4 Thoughts and Implications: How to Better Leverage China's Scale Advantages?

3.4.1 Correcting Defects in Market Mechanisms and Expanding the Domestic Market

Attaching importance to scale advantages on the demand side and promoting internal market competition. Economies of scale come from specialized division of labor and transactions, for which the key foundation lies in a large scale, well-developed market economy mechanism. On the one hand, China has a large population and economy, but its scale advantages on the demand side still have upside potential. The experience of many countries shows that prioritizing income equity is the foundation for the formation of a large consumer base. At present, China is working to build an olive-shaped society. Accelerating the formation of an income distribution structure "with large middle and small ends" is conducive to the formation of a robust domestic market with abundant demand for domestic products, which could lay a basis for China to leverage scale advantage as a large country.

On the other hand, in addition to the scale of population and consumer markets, another key factor for leveraging scale advantage is the development of a market economy. A well-developed market economy can facilitate division of labor and transactions, and enable large countries to more effectively translate their large populations and economies into competitive advantages. This is particularly evident in the comparison of growth between the US and the former Soviet Union. However, there are two potential challenges with the market economy—i.e., externalities and monopoly, which are correlated to each other. In view of these two issues of market mechanisms, efforts could be made to promote internal market competition, reduce the negative impact of externalities and monopoly, and effectively coordinate the relationship between economies of scale and the market economy, in our opinion.

Correcting externalities, increasing the supply of high-quality public goods, and strengthening financial regulation. On the one hand, the supply in areas such as transportation and commercial infrastructure, education, healthcare, and sci-tech innovation are crucial to improving the level of integration of the domestic market. However, these areas have strong positive externalities, making it difficult for the private sector to effectively provide related goods or services. It may lead to additional inequality as private sector market agents could charge high premiums. Therefore, as a large country, public spending can be more widely spread in China. Leveraging such an advantage, China could increase public investment to make up for the shortcomings of the market system. In addition, experience from the PV and communications industries shows that the government can create considerable market demand for related industries and promote mass production while it increases the supply of public goods. In fact, this is what the US government did in the nineteenth century, including accelerating the construction of a nationwide railway network and establishing institutions such as the United States Geological Survey (USGS) to train much-needed talent.

On the other hand, financial institutions may leverage the government's credit guarantee to promote the integration of financial and industrial businesses and seek higher returns by taking greater risks. The integration of financial and industrial businesses not only results in non-competitive monopoly but also frees institutions from market incentives and constraints, bringing negative externalities to the entire market economy. At present, a small number of enterprises are blindly expanding into the financial sector in China, leading to continuous accumulation of risks.[55] According to the US experience and that of other countries since 1933, to resolve risks associated with these financial groups, measures could be taken to strengthen regulation and reduce negative externalities—i.e., promoting the separation of the financial sector from industrial sectors, and separation of various financial sub-sectors from each other.

Adhering to anti-monopoly measures and participating in international competition to mitigate obstacles to innovation from large knowledge-based companies. A key feature of the knowledge economy, especially the digital economy, is stronger economies of scale and scope. China can better coordinate the relationship between scale and monopoly, and leverage its enormous domestic market to cultivate large-sized digital companies to help domestic industries outperform in international competition. However, that also means leading companies may accumulate market power, hindering market competition, industrial innovation, and economic efficiency. To address this, we believe China can first adhere to anti-monopoly measures, regulate against unfair competition, improve the competitiveness of knowledge-based industries, and mitigate the damage to innovation and economic efficiency caused by leading companies. In addition, measures could also be taken to encourage leading companies to move toward globalization, benefiting the domestic market and improving economic efficiency by engaging in more extensive competition.

However, stronger economies of scale of the knowledge economy also means that governments in various countries might have a tendency to restrict access of companies from other countries. For example, they may erect trade barriers such as technology standards, cross-border digital governance, and privacy protection, among others. In order to address this problem, China can actively explore rules-based cooperation with other countries via trade agreements and industrial policies, among others, so as to create a fairer and more favorable international environment for its knowledge-based industries to explore the international market and drive the development of the knowledge economy, in our opinion.

Diseconomies of scale in land sectors come from the intertwining of externalities and monopoly. As mentioned earlier, land sectors may cause a squeeze on the real economy at the macro level. For example, slow productivity growth in land sectors drags down overall productivity, and real estate prices could negatively affect

[55] Financial Stability Analysis Group of the People's Bank of China. *China Financial Stability Report 2020*. China Financial Publishing House, 2020.

households' purchasing power. At the micro level, land leads to diseconomies of scale as it is a natural monopoly. Moreover, the externality and monopoly of land sectors are entangled with each other, as the natural monopoly of these sectors reinforces the squeeze on other industries, which in turn strengthens the monopoly position of such sectors. The aforementioned characteristics of land sectors mean that they impose severe constraints on economies of scale. Therefore, related departments could consider containing the excessive development of land sectors, especially excessive land financialization. In addition, while abiding by the principle of "houses are for living in, not for speculation", measures could be taken to address reasonable housing demand—e.g., by increasing the supply of government-subsidized housing, to unleash the vitality of the market economy.

3.4.2 *Taking Advantage of the Domestic Market and Strengthening Cooperation in Cross-Border Industry Chains*

Deglobalization has strengthened the dominant position of large countries in global industry chains. Compared with the round of deglobalization between the two world wars, the current round of deglobalization is less ubiquitous and intrusive, and various countries have not yet returned to a state of erecting barriers to trade or immigration.[56] However, similar to historical experience, the current round of deglobalization has increased the importance of domestic markets, as evidenced by various countries' move to partially replace the global market with their domestic markets. In other words, the new round of deglobalization requires countries to strengthen cross-border economic and trade cooperation within closely connected countries and regions on the basis of facilitating economic flows in the domestic market. As a result, the division of labor in global industry chains features "multipolarity", with different "major powers" interconnected and competing with each other. From such a perspective, we believe China can leverage the scale advantages of its domestic market to play a more proactive role in organizing, coordinating, and even reshaping transnational industry chains.

Building advantageous domestic industry chains and enhancing integration among different parts of industry chains. First, China can build competitive industry chains to address demand in the domestic market. While supporting leading domestic companies to expand operations and gain dominant positions in industry chains, measures could also be taken to encourage these companies to lead the upstream and downstream of the domestic industry chains to grow together. Second, the experience of the US and other countries shows that large countries' scale advantages can help strengthen integration among different parts of their industry chains. Given this, China could encourage domestic industries to expand to upstream

[56] O'Rourke, Kevin Hjortshøj. "Economic history and contemporary challenges to globalization." *The Journal of Economic History* 79.2 (2019): 356–382.

industries (i.e., R&D and design as well as key parts and components) or to downstream industries (i.e., sales and after-sales services) so as to leverage industry chains and consolidate their competitive advantages in more links. Third, backed by its enormous domestic market, China has the ability to develop more industrial clusters, in our view, which constitutes a competitive advantage. Therefore, China can also encourage the development of multiple industry chains and complete industry chains in different regions, and eventually form a differentiated regional industrial landscape based on local characteristics.

Strengthening in-depth industry chain cooperation with other countries based on domestic advantages. With a focus on the domestic industry chain, China can strive to coordinate the relationship between its domestic industry chain and regional and global industry chains. First, China could proactively encourage other countries (especially those with close ties with China and located in neighboring regions) to deeply integrate into China's advantageous industry chain, form a regional industry chain, and amplify and share economies of scale through in-depth intraregional cooperation. Second, China can also take the lead in strengthening ties with other regional industry chains and lead countries in those regions to integrate into global competition and cooperation. In particular, as global industry chains develop towards multipolarity, large countries play a more prominent role in leading cross-border cooperation—China, as a large country, could also play a key role. For example, leveraging its large domestic market with strong demand, the US not only strengthened its industry chain integration with its neighboring countries Canada and Mexico through the United States-Mexico-Canada Agreement (USMCA), but also strengthened industry chain cooperation within the country itself, the region in which it is located, and other regions of the world by signing trade agreements such as the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and the Indo-Pacific Economic Framework for Prosperity (IPEF).

Encouraging domestic industries to move up the industry chain through cross-border cooperation and enhancing the leading role of large countries. In the context of deglobalization, large countries focus more on their domestic markets. However, this does not mean that they should revert to being closed economies. Instead, large countries such as China could leverage their enormous domestic markets to drive industrial development, then give a boost to the development of domestic industries by participating in international competition, in our opinion. For China to achieve this goal, efforts can be made on at least three fronts. First, encouraging domestic companies to actively participate in innovation and international competition to leverage industry chains, or even become chain leaders, so as to consolidate China's advantages. Second, leveraging cross-border industry chain integration to promote domestic industrial upgrading and expand the number of advantageous domestic industries. More specifically, the country could leverage its enormous domestic market and cross-border cooperation to encourage and help domestic industries access high-end technological areas, make key breakthroughs in areas such as core components, and serve the development and upgrading needs of domestic industries. Third, given its scale advantages as a large country, China is characterized by more specialized division of labor among industries, making it more necessary to deepen exploration in industrial segments with smaller size and higher complexity in the global markets. We believe this will help enhance the core position of Chinese industries in regional and global industry chains, and help it lead countries in the region to participate in international competition. In practice, policy support can be provided to reduce the costs of trial and error, and create favorable conditions for industrial development and upgrading.

Chapter 4
Pursuit of Prosperity Amid Changes: Evolution of Trade Rules and Global Industry Chains

Abstract Trade rules refer to a series of agreements by which countries must abide in international trade. Countries around the world are recognizing the need to enhance their security as their industry chains become globalized. This is occurring amid widespread change spurred by geopolitics. We believe trade rules may gradually evolve from being dominated by the World Trade Organization (WTO) to a new stage of parallel development of the WTO and preferential trade agreements (PTAs). Looking ahead, we expect the WTO and PTAs to put pressure on each other and evolve simultaneously to reshape the global trade landscape. We think the WTO will continue to play the basic function of adjudication and facilitate basic consensus in a wide range of fields, while PTAs will play a more obvious leading role in rule-making in emerging fields. This should drive in-depth integration of regional economies and trade.

The evolution of trade rules could increase uncertainty in global industry chains in the near term and affect changes in the global industry chains in the medium and long term. First, the transition from offshore outsourcing to nearshore and friendly-shore outsourcing may become increasingly prominent along the industry chains. Second, as the influence of major countries on the evolution of trade rules increases, regionalization of industry chains surrounding major countries should become more prevalent. Lastly, some emerging industries may see opportunities for further opening-up under new trade rules. We expect labor-intensive industries to be relatively less affected by the evolution of trade rules, while capital- and technology-intensive industries such as machinery and electronics industries may be more severely affected as the global development of their industry chains is more susceptible to far-reaching PTAs.

Currently, we think China's trade rule system is yet to fully support the efficient and safe development of industry chains. First, China's influence is comparatively modest in the global multilateral trade system, so it's hard for the country to provide strong impetus for WTO reform. This means the development of China's industry chains is subject to external pressure. Second, some regional trade agreements China initiated or participated in are still in the preliminary stage of development in terms

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of depth and breadth, and could play a limited role in facilitating in-depth industry chain integration in the short term. Third, China's institutional arrangements for opening-up still have room for refinement, and the country's ability to align itself to high-standard international economic and trade rules remains limited. We believe this may hinder its further integration into global industry chains to some extent.

Looking ahead, we think China could adapt to the evolution of trade rules and facilitate complementary and common development of multilateral trade, regional trade, and domestic market rules. Under the multilateral system, China can actively participate in the reform of the WTO, seek common ground while reserving differences, build consensus, and drive a multilateral cooperation platform. In regional markets, China could adopt a multi-level development strategy and upgrade regional trade agreements. In the domestic market, efforts could be made to advance a high-standard institutional opening-up with pilot free trade zones acting as test fields.

Keywords Global industry chains · WTO · Preferential trade agreements · Trade rules

The wave of globalization since the 1980s has driven the rapid development of the global economy, an important manifestation of which is trade liberalization. Over the past 40 years, global merchandise trade grew at a CAGR of 6.3%, higher than the 4.1% CAGR of global GDP. However, in recent years, under pressure from the COVID-19 pandemic, geopolitical conflicts (e.g., the Russia-Ukraine conflict), and economic and technological competition among major countries, some economies have resumed trade protectionist policies to maintain the security of their industry chains. As such, deglobalization has gradually changed from thoughts and ideas into actions.

In retrospect, free trade has not always been the dominant theme of global trade over the past century. In the 30 years from 1914 to 1945, affected by the two world wars, the Spanish flu of 1918, and the Great Depression of the 1930s, various countries ramped up trade protectionist policies and tariffs, which led to a contraction in global trade. What are the differences between the current round of "deglobalization" and previous ones? Will countries become more closed off in industrial development, or will they continue to seek security amid opening-up policies? What are the opportunities and challenges faced by China and how can it cope with them? In this chapter, we will answer these questions from the perspective of international trade rules.

4.1 Trade Rules: A Perspective for Understanding Global Industry Chains

In the international trade system, the trade behavior of each country is not only affected by its own trade policies, but also trade rules—i.e., agreements, laws, practices, and models by which all countries need to abide. Written trade agreements are the most common trade rules. Trade rules can be divided into two types of trade agreements. First, WTO agreements, which are based on multilateral principles and characterized by inclusiveness. Second, PTAs are based on unilateral or plurilateral negotiations and can be discriminatory.[1] In addition, under the two types of trade agreements, it is possible to develop highly differentiated trade provisions such as specific tariffs, investment, and competition policies.

Trade historian Douglas Irwin once spoke highly of trade rules. According to Irwin, the prosperity of the world economy over the last half century owes a great deal to the growth of world trade which, in turn, is partly the result of farsighted officials who created the General Agreement on Tariffs and Trade (GATT). They established a set of procedures which gave stability to the trade-policy environment and facilitated the rapid growth of world trade. With the long run in view, the original GATT conferees helped put the world economy on a sound foundation and improved the livelihood of hundreds of millions of people.[2] This comment affirms the contribution of trade rules and clarifies that they lay "a sound foundation" for improving economic efficiency and, ultimately, national welfare. They do so by creating a global environment with low trade barriers. The functions of trade rules are reflected in two ways:

The most direct function of trade rules is to act as an "accelerator" for promoting the development of industrial trade. Figure 4.1 reviews the overall impact of more than 220 trade agreements on international trade over the past 60 years, and we note that trade agreements played a significant role in promoting trade development. In particular, intra-regional trade creation (i.e., trade flows between members) increased by 24% on a net basis thanks to the facilitation of internal trade within the region. With the integration of regional trade, member countries' external demand for imports shrank, and trade flows from the rest of the world to the agreement zone decreased by a net 32%. More importantly, trade agreements facilitate industrial agglomeration and economies of scale within regions, and enhance the region's overall economic strength. This has driven a net increase of 39% in extra-regional trade creation (i.e., trade flows from the agreement zone to the rest of the world).

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[1] According to the definition of scholars such as Limão (2016), Frankel et al. (1997), Baier et al. (2014), there are six types of PTA: Non-reciprocal PTA (NRPTA), reciprocal PTA (RPTA), free trade area (FTA), customs union (CU), common market (CM), and economic union (EU); PTA cover a range of topics such as tariffs, factors, technologies, and environment in terms of content. Therefore, PTA in this report is a broad concept, which covers various non-multilateral free trade agreements such as FTA and soft trade rules such as IPEF.

[2] https://www.wsj.com/articles/SB117607482355263550.

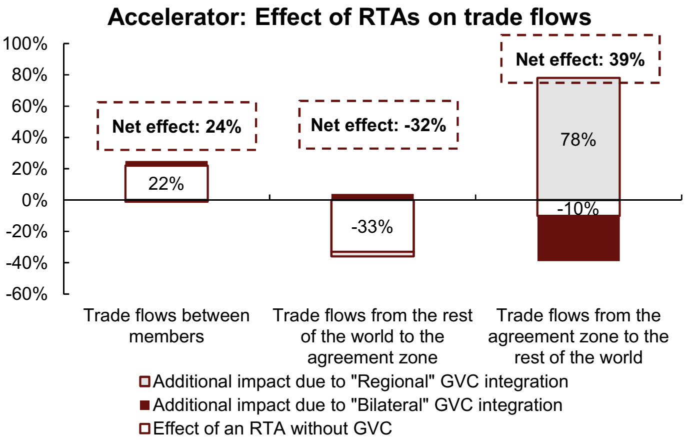

Fig. 4.1 Trade rules can act as an "accelerator" for industry chains. *Note* GVC refers to global value chain. *Source* François de Soyres et al., Regional Trade Agreements with Global Value Chains, FEDS Notes, February 2021, CGI

Trade rules can also act as a "stabilizer" for industry chains and alleviate pressure on industry chain operations, which is particularly important in the current international environment. Without adequate constraints from trade rules, international trade may face a so-called prisoner's dilemma, leading to stagnated development of global industry chains. According to a study by economist Avinash Dixit, in a world without trade rules, in which countries could benefit from erecting trade barriers—e.g., by levying an import tariff to improve their terms of trade—and provide subsidies to large firms to help them capture profit in oligopoly situations, such behavior would distort free trade and provoke retaliation from other countries. The absence of trade rules to restrict and punish such behaviors would eventually bring global industry chains to a standstill.[3] In reality, as shown in Fig. 4.2, uncertainty in trade policy rose significantly after the COVID-19 outbreak, becoming a drag on global supply chains.

By working as an "accelerator" and "stabilizer", effective trade rules can increase economies of scale and form a larger, connected market on the basis of complementary advantages and free trade. First, the flow and agglomeration of factors within a region could become more efficient in a connected market, extending the boundaries of economies of scale. Second, building a connected market means that trade policies of different countries are unified and predictable, which should reduce the cost of trade frictions between different countries and enlarge the room for production and sales growth in member countries.

Over the past 40 years, the trend of globalization has given rise to three production and export hubs—the US, Germany, and China. Multiple markets of different sizes

[3] Dixit, Avinash. "*International Agreements for Trade Liberalization.*" Princeton University, Spring 2010.

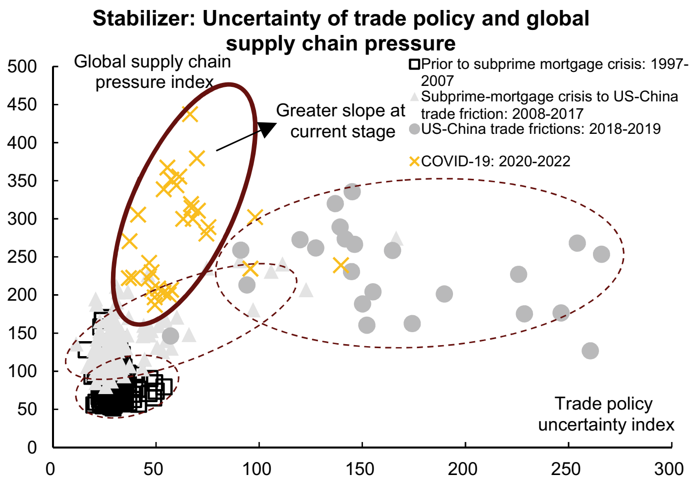

Fig. 4.2 Trade rules can act as a "stabilizer" for industry chains. *Source* New York Fed, Trade Policy Uncertainty Index, CGI

and with connected industry chains have been established around these three hub countries. In this process, member countries can significantly benefit from economies of scale brought about by trade rules, with large economies being the major beneficiaries. According to a study, the US has been estimated to have made US$127bn in additional gains each year thanks to "extra" trade growth fostered by the North American Free Trade Agreement (NAFTA), accounting for about 0.93% of its GDP.[4]

In fact, not only have trade rules evolved along with the development of industry chains, but they have also acted as a driving force in reshaping industry chains. For example, trade in intermediate goods has given rise to new terminology related to global industry chains, and the rapid development of the digital economy has driven countries to negotiate terms of digital trade. At the same time, the evolution of trade rules provides new impetus and constraints for the development of industry chains. For example, after the establishment of the WTO, some complex industry chains with long processes and that require cross-border assembly of components such as home appliances, automobiles and high-end equipment have benefited significantly from tariff cuts.

[4] CRS Report for Congress. Knowledge at Wharton. PIIE BRIEFING No14-3, November 2014.

4.2 Trend Amid Deglobalization: From a Multilateral Mechanism to a Multilateral Mechanism Plus Regional Mechanisms

4.2.1 Economic and Political Factors Dominate the Evolution of Trade Rules

International trade has a long history. International trade took shape as early as the Age of Discovery in the fifteenth and sixteenth centuries. However, before the end of the Second World War in 1945, there was no extensive global trade coordination mechanism.[5] During that period, countries followed the traditional trading model of exchanging manufactured products and raw materials. Even during the first round of globalization from 1870 to 1914, the average global tariff rate did not decline, and trade flows were still reflected mainly in the movement of people rather than freight. For example, in the decade between 1896 and 1906 alone, the number of international migrants doubled.[6] However, global exports as a percentage of GDP remained largely stable.

During the period encompassing the two world wars, pandemic outbreaks and geopolitics highlighted the disadvantages of a lack of coordination in international trade. After the First World War, which began in 1914, the wave of globalization gradually faded. With the outbreak of the Spanish flu of 1918 and the rise of trade wars and nationalism in 1920s and 1930s, the trend of deglobalization gradually intensified, as evidenced by the widespread adoption of protectionist trade policies in various countries, and substantial tariff increases aiming at protecting domestic "infant industries" and maintaining fiscal revenue. For example, in 1915, the British Parliament raised the import tariff on automobiles and watches to 33.3%,[7] and in 1930, the Smoot-Hawley Tariff Act was passed in the US, which raised tariffs on all imported goods. These unilateral protectionist policies eventually led to a sharp contraction in global trade.

Driven by economic factors, developing international trade rules became a shared aspiration after the Second World War. The theory of free trade, which draws on work from economists such as Adam Smith and David Ricardo, went mainstream following the two world wars. As they reexamined the damage and destruction to the global economy and the international order caused by the Second World War, various countries started to show unanimous support for the establishment of a multilateral trading system and trade liberalization.[8] Led by the US, 23 member countries, including the UK, Canada, and Australia, signed GATT, which drove a significant decline in the

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[5] Ravenhill, John, ed. *Global political economy*. Oxford University Press, 2017.

[6] McKeown, Adam. "Global Migration, 1846-1940." *Journal of World History* (2004): 155–189.

[7] https://hansard.parliament.uk/Commons/1925-05-07/debates/27851cfe-0bcf-4094-9fe5-8468c1a17a15/MckennaDuties.

[8] VanGrasstek, Craig, and L. A. M. Y. Pascal. *The history and future of the World Trade Organization.* Geneva: World Trade Organization, 2013.

global average tariff and opened a new chapter of globalization. GATT, which gradually morphed into the WTO, laid a solid foundation for the current multilateral trade system.

As the rise of Japan and Europe led to changes in the international economic and trade landscape, trade rules also underwent changes again driven by economic and political factors. From the end of the Second World War to the 1960s, the US remained the world's most powerful country in terms of industrial production, accounting for about 50% of the world's manufacturing output,[9] and it was also the world's largest exporting country. In the meantime, Japan and Europe recovered rapidly after the war. In 1965, the US recorded a bilateral trade deficit with Japan for the first time, and the trade deficit gradually widened, posing challenges to the US's economic status. In order to eliminate the trade deficit and protect its position in the international market, the US then imposed sanctions on Japan's textile, TV, steel, automobile, and semiconductor industries, and put further pressure on Japan through the Plaza Accord in 1985 and the Japan-United States Structural Impediments Initiative in 1989. Overall, trade rules during that period were affected by both economic and political factors and were designed to serve the interests of major countries; for example, the US leveraged its dominant position in GATT to sign the Multifiber Arrangement with 40 countries and regions, which saw these countries voluntarily limit exports to the US.

With the rise of developing countries, economic factors once again dominated the evolution of trade rules, and the world entered a trade boom. In the 1990s, industrialization accelerated in developing countries such as China and Vietnam, setting stage for the formation of global industry chains. Driven by the offshoring and outsourcing activities of multinational companies in developed countries, developing countries benefited notably from industrial transfers by leveraging their low labor costs. The pattern of the international division of labor changed from an inter-industry division of labor to an intra-industry division of labor. The determining factor for division of labor in various countries changed from a comparative advantage in products to a comparative advantage in factors. Driven by economic benefits, the Tokyo Round (from 1973 to 1979) and the Uruguay Round (from 1986 to 1993) of multilateral trade negotiations (MTN) resulted in average tariff reductions of 35% and 39%,[10] respectively, driving a sharp drop in the average global tariff rate to around 3.5%.[11] Against such a background, international trade witnessed an unprecedented boom over 1990–2007, with global exports growing at a CAGR of 6.2%, much faster than the 3.2% GDP growth over the same period.[12]

While the global financial crisis put a pause on the second round of globalization, competition among major countries for international status and influence once again drove international trade rules to a new stage of development oriented by political

[9] 60 Days USA. What Happened to the U.S. Manufacturing Industry? April 2021.

[10] Ravenhill, John, ed. *Global political economy*. Oxford University Press, 2017.

[11] Source: World Bank.

[12] Data are in constant 2015 constant prices, expressed in US dollars. Source: World Bank.

considerations. Global trade and value chain expansion plateaued after the financial crisis, and participation in the global value chain declined notably over 2010–2016.[13] WTO reform stalled, with the US, China, and the EU at odds with each other on reforms in key areas such as dispute settlement, SOE protection, and industrial subsidies.[14] Regional trade agreements (RTAs) among countries and regions with close economic and trade ties and consistent political stances, as represented by PTA, began to emerge in large numbers. In 2009 alone, 21 PTAs took effect, showing a clear domino effect. Intensifying competition among major countries and various geopolitical factors shifted the basis for international trade rules from efficiency to security. Developed countries such as the US shifted the focus of international trade negotiations from multilateral negotiations to regional ones. It launched negotiations related to the Trans-Pacific Partnership (TPP) and the Transatlantic Trade and Investment Partnership (TTIP), and built alliances in Asia through the Indo-Pacific Economic Framework for Prosperity (IPEF). Such a shift also meant that international trade rules gradually evolved from being dominated by multilateral mechanisms to both multilateral and regional mechanisms.

4.2.2 Global Trade Rules: Towards a New Stage of Development Driven by Both Multilateral and Regional Mechanisms

In recent years, trade liberalization has faced unprecedented challenges under the pressure of global public health crisis, geopolitical conflicts, and competition among major countries. However, unlike in 1914–1945, when globalization ebbed for the first time, industry chains of different countries are now deeply integrated and trade in intermediate goods is developing rapidly. It is now difficult for individual countries to cut international ties and adopt independent trade protectionist measures. Countries are more inclined to build alliances to enhance security while maintaining openness. Therefore, demand for openness is not weakening. However, we think the key for individual countries is to determine with whom they should cooperate and how to achieve openness. This also means international trade rules will likely move towards higher levels of flexibility and autonomy under the influence of political factors. Both WTO-based multilateral mechanisms and PTA-based regional or group agreements will likely play important roles in their respective fields.

Of course, WTO and PTAs are not separate from each other. The two put pressure on each other and jointly drive the continuous evolution of international trade rules. PTAs put pressure on the WTO, and drive the WTO to carry out reforms by playing experimental and exemplary roles. For example, in the 1990s, the US

[13] XING, Yuqing, Elisabetta Gentile, and David Dollar. "Global value chain development report 2021: Beyond production." (2021): 1.

[14] WU Chaoyang, and WU Chan. "WTO Reform: Position Comparison of Representative Members and the Prospect." *Intertrade* 9(2021):61–68.

launched NAFTA negotiations during the Uruguay Round of negotiations, and introduced the higher-standard investment and intellectual property protection provisions in NAFTA into the drafting of the WTO Agreement on Trade-Related Investment Measures (TRIMS) and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).[15] The multilateral rules laid down by the WTO also drove regional cooperation to a deeper level. For example, the 12th Ministerial Conference (MC12) of the WTO adopted the Ministerial Draft Agreement on TRIPS in June 2022, allowing countries to use patents necessary for the production and supply of COVID-19 vaccines without the patent owner's permission in response to the COVID-19 pandemic. This move may significantly affect PTA rules on public health crisis response in the future.

Looking ahead, we believe the inclusiveness of economic development and national security among major countries will determine future development of international trade rules. It is possible that countries will reach a multilateral consensus, WTO reform resolves its impasse, PTAs become more inclusive, countries integrate more deeply in institutional arrangements, and the WTO and PTAs drive globalization forward. Such a trend occurred in the 1990s, most notably in the negotiations of the Information Technology Agreement (ITA), which was initiated by Europe and the US in the TransAtlantic Business Dialogue (TABD) in 1995. After gaining the support of APEC members, the initiative was submitted to the WTO. Negotiations concluded in 1997, and ITA became a plurilateral agreement. On the contrary, it is also possible that competition between major countries will intensify, WTO reform will stagnate, and PTAs will become tools for core countries to form opposing alliances. In this scenario, deglobalization could intensify.

At the same time, with the development of the global economy, the wide application of new technologies, and the emergence of new challenges, we think the development of WTO and PTAs will show new characteristics. Specifically, the WTO may exhibit three trends involving its adjudication function, negotiations in specific areas, and its operating mechanism.

First, the multilateral trading regime with the WTO at its core has been the cornerstone of international trade, and we believe the WTO will continue to play a basic adjudicative function. Despite criticism of its dispute settlement mechanism, the WTO's international judicial mechanism handles the most cases of any such body in the world. Dispute settlement bodies became increasingly active over 2014–2018, before the US began influencing the selection of justices on WTO Appellate Body.[16] And despite its discontent, the US has filed 124 dispute cases at the WTO to address trade subsidies, anti-dumping, and intellectual property protection.[17] Looking ahead, the rules-based multilateral trading system could remain the cornerstone of international trade and negotiations. As the guardian of the multilateral system, the WTO

[15] USITC. US Trade Policy since 1934. 2009.

[16] YU Peng. "The Crisis of the WTO Dispute Settlement Mechanism: Reasons, Progress and Prospects." *International Trade* 5(2019):9.

[17] Statistics as of October 31, 2022. Source: https://www.wto.org/english/tratop_e/dispu_e/dispu_by_country_e.htm.

could still provide a platform for exchanges and opportunities for consultation among heads of state. As such, it could resist pressure from protectionist policies and provide a high degree of certainty for trade policies.[18]

Second, despite the slow progress of the Doha Round of negotiations, efforts have also been made under the multilateral mechanism to explore new ways to provide basic consensus for the formulation of trade rules. Why has no important WTO framework agreement emerged since the end of the Uruguay Round of negotiations? The core reason lies in the WTO's negotiation system—under the traditional principle of reaching decisions by consensus, all 164 member states must reach consensus on any proposals. However, countries' aspirations and stages of development often vary widely, making it difficult to achieve results under this way of negotiation. The Open Plurilateral Agreement (OPA) under the WTO framework provides a possible solution. It was negotiated, adopted, and operated by WTO members. The results of the negotiations can be used only among participating countries or extended to nonmembers on a most favored nation (MFN) basis.[19] This means that if differences between countries cannot be addressed in the short term, agreements can be formed among countries with a high degree of consensus before gradually evolving to multilateral rules. For example, the Environmental Goods Agreement (EGA) launched in 2014 has gone through 18 rounds of negotiation. It has 28 participating members and covers about 54 environmental products. In terms of digital trade, 71 member states issued the Joint Statement Initiative (JSI) on future negotiations on e-commerce in 2017, and the 2021 plurilateral agreement negotiations on e-commerce have made progress on eight articles, including consumer protection, electronic signatures and authentication, and paperless trading.[20]

Finally, major countries will play an increasingly important role in the operation of multilateral mechanisms. From the establishment of GATT to that of the WTO, the operation of the multilateral trading system has been inseparable from the leading roles of major countries in global governance.[21] Major WTO negotiations have stalled since 2018. During that time, the EU, China, and the US have released documents in an effort to advance WTO reform. However, there are still disagreements on key issues such as reform of the dispute mechanism, recognition of developing country status, and industrial subsidies. While the necessity of WTO reform is widely recognized at present against a background of "governance deficit", the pace of reform may depend on major countries' willingness to reform and whether they can reach consensus. Progress in reforms has been limited so far.

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[18] Rocha, Nadia, and Robert Teh. "Preferential trade agreements and the WTO." *VoxEU. org* 21 (2011).

[19] Nakatomi, Michitaka. "Plurilateral agreements: A viable alternative to the World Trade Organization?." *A World Trade Organization for the 21st Century.* Edward Elgar Publishing, 2014. 361–402.

[20] WTO. WTO Joint Statement Initiative on E-commerce: Statement by Ministers of Australia, Japan and Singapore. June 2022.

[21] VanGrasstek, Craig, and L. A. M. Y. Pascal. *The history and future of the World Trade Organization.* Geneva: World Trade Organization, 2013.

On the basis of the multilateral system, we think PTAs could play a more important role in three aspects, i.e., playing a leading and exemplary role in rule-making, integrating regional economies, and focusing on industrial policies.

First, PTAs could play a leading role in rule-making in emerging fields. As the number of PTA member countries is much smaller than that of WTO member countries, negotiations face fewer obstacles and could be more focused, as reflected by in-depth PTA clauses, faster pace of upgrading, and better implementation. For example, based on the WTO Agreement on TRIPS, PTAs in various countries have expanded the scope of intellectual property protection based on their own characteristics. Specifically, Japan and South Korea emphasize extended patent protection, the US pays attention to copyright protection, and the EU attaches importance to geographical indications.[22] In addition, PTAs have clearer and more targeted standards and implementation procedures than TRIPS. As digital and green topics become increasingly important, we expect PTAs to play a bigger role in leading the upgrading of rules. For example, the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), the United States-Mexico-Canada Agreement (USMCA), and the Regional Comprehensive Economic Partnership (RCEP) all contain rules on digital trade. The USMCA adopts more aggressive digital trade provisions, requiring that platforms are not held liable for third party content and banning customs duties on digital services.[23] We believe the contents of these agreements provide a reference and guidance for defining, standardizing, and identifying fulfillment risks in digital trade under future PTAs. In addition, compared with OPA negotiations under the WTO framework, which usually focus on a specific topic, PTAs cover a wide range of topics and can innovate and upgrade provisions in many emerging fields, making them a bellwether for reforming trade rules.

Second, a number of large regional trade agreements have emerged to create a new pattern of regional integration. In recent years, large regional trade agreements such as CPTPP and RCEP have emerged, facilitating the formation of a new pattern of regional integration by integrating regional economic and trade ties and rules and systems. First, integration of scale: Large-scale regional trade agreements cover a large number of countries and economies, delivering strong trade creation and trade diversion effects. For example, the United Nations Conference on Trade and Development (UNCTAD) estimates that RCEP's trade creation effect would stimulate trade between members by US$17bn, while its trade diversion effect could total US$25bn; the sum of these two figures is equivalent to 18.3% of intra RCEP-trade in 2019.[24] Second, integration of rules: Large regional trade agreements could unify higher-standard rules in a larger scope. For example, the TPP has 26 provisions, nearly half

[22] Maskus, Keith E., and William Ridley. "Intellectual property-related preferential trade agreements and the composition of trade." *Robert Schuman Centre for Advanced Studies Research Paper* 2016/35 (2016).

[23] Burri, Mira. "Towards a new treaty on digital trade." *Journal of World Trade* 55.1 (2021).

[24] Nicita, Alessandro, et al. "A New Centre of Gravity-the Regional Comprehensive Economic Partnership and its Trade Effects." *United Nations Conference on Trade and Development (UNCTAD).* 2021.

of which are not found in other free trade agreements implemented in the Asia–Pacific region, including those involving agriculture, labor standards, environment, and small and medium-sized enterprise (SME) subsidies. The Transatlantic Trade and Investment Partnership (T-TIP) echoes the TPP in several ways,[25] reflecting the US and EU's intention to achieve unification in rule-making with the Asia–Pacific region through trade agreements.

Lastly, coordination between PTAs, one of the core foreign trade policy tools of major countries, and these countries' domestic industrial policies could be strengthened. For example, in the past decade, the US has focused on emerging industries such as chips, biomedicine, big data, AI, IT, and finance in CPTPP and TTIP negotiations and in USMCA documents in an attempt to strengthen its domestic industries.[26] At the same time, the US's industrial policies and national security policies also emphasize its leadership in strategic emerging industries and the importance of fending off competition from external parties. Specifically, the rules of origin clause in PTAs may become a restrictive measure, and PTAs themselves can also be used to extend industrial policies to the trade area. For example, the US recently introduced the Inflation Reduction Act, which states automobile manufacturers should source at least 40% of critical battery minerals domestically or with free trade partners starting in 2023.[27]

4.3 Global Industry Chain: Regionalization Gathering Momentum Amid a Rising Level of Uncertainty

On the surface, trade rules have evolved from being dominated by the WTO towards a spiral pattern development amid interaction between the WTO and PTAs. In essence, the evolution of trade rules has brought about changes on multiple fronts, e.g., the development of global industry chains and cooperation. When trade rules were driven by economic factors, efficiency was the core development goal of industry chains. However, as political considerations are increasingly reflected in trade rules, more importance will be attached to the security of industry chains. This is reflected by the growing trend of regionalization and diversification of industry chains, the possible shortening of some industry chains, and the transformation from shallow integration of industry chains to deep integration.[28] So specifically, how do trade rules affect industry chains? How does their impact differ for different industry chains? We answer these questions in the following section.

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25 SHEN Minghui. "Mega Free Trade Agreement: Stepping Stones toward Multilateral Rules." *New Horizons* 6(2014):5.

26 WANG Meimei, and XU Qianyu. "Strategic Exclusivity and Rule Restructuring: Analyzing the Trade Policy Implications of US FTAs." *International Business Research* 42.4(2021):13.

27 https://www.congress.gov/bill/117th-congress/house-bill/4346/text.

28 Dadush, Uri. "The future of global value chains and the role of the WTO." (2022).

4.3.1 Reshaping Global Industry Chains: Transfer of Industry Chains, Regional Agglomeration, and a New Opening-Up

We think uncertainties about the development of global industry chains will increase as reforms of multilateral rules stall. The operation of global industry chains is inevitably subject to disputes, and the settlement of such disputes needs to rely on WTO dispute settlement mechanisms. For example, China won the DS437 case (China challenged US countervailing duty measures against Chinese exports of oil well pipes and other products to the US on the grounds they violated WTO-covered agreements) and was authorized to impose tariffs on imports from the US totaling up to US$645 mn a year to maintain normal competition in the industry chain. We believe the stable operation of global industry chains is in urgent need of protection from multilateral rules. For example, during the COVID-19 pandemic, many countries took trade protectionist measures to serve their own needs for industrial security, which hindered the free development of global industry chains, and even severed or disrupted some chains. We think the evolution of trade rules on global industry chains will be reflected in three ways.

First, policies that are not conducive to free trade could increase substantially, and the transition from offshore outsourcing to nearshore and friendly-shore outsourcing may ramp up along the industry chains. According to Global Trade Alert, the number of policies that are not conducive to free trade rose from 217 in 2012 to 2,137 in 2022, implying a CAGR of 23.1%, and posing two challenges to traditional offshore outsourcing. Against a background of increasing emphasis on the security of industry chains, major countries are more inclined to locate their industry chains in neighboring areas within closer geographical proximity, i.e., nearshore or backshore outsourcing. According to a Kearney survey, in 2021, about 70% of US CEOs planned to relocate partial manufacturing operations to Mexico to strengthen their control.[29] In addition, it could be more difficult to reach new PTAs amid uncertainties over the trade environment and policies.[30] This is illustrated by increased average distance between member countries of newly signed PTAs and increased cooperation between countries with shared values, i.e., the so-called friendly-shore outsourcing.

Second, as major countries' influence on the evolution of trade rules increases, the effect of regional industry chains surrounding major countries may become more prominent. Studies show that the effectiveness of trade agreements on industry chains increases as the number of member countries increases and the trade provisions go deeper.[31] Reaching PTAs with such characteristics requires increased participation of

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[29] Kearney. 2021 Reshoring Index: The Tides are Tuning. 2022.

[30] Limão, Nuno. "Preferential trade agreements." *Handbook of commercial policy.* Vol. 1. North-Holland, 2016. 279–367.

[31] Osnago, Alberto, Nadia Rocha, and Michele Ruta. "Deep agreements and global value chains." *Global Value Chain Development Report* (2016). Baccini, Leonardo. "The economics and politics of preferential trade agreements." *Annual Review of Political Science* 22 (2019): 75–92.

great powers as major countries exhibit more obvious advantages in negotiations in areas such as scale, market access, and politics.[32] Against such a background, regional industry chains with major countries at the core may become increasingly influential. For example, mega-regional trade agreements such as the EU, NAFTA, and RCEP all set specific regional development provisions targeting the automobile industry chain. NAFTA stipulates that only products with a minimum regional value content (RVC) of 62.5% can enjoy preferential tax treatment, and the USMCA required an upwards adjustment to the RVC requirement from 62.5% under NAFTA to 75% under the USMCA to strengthen PTAs' binding effect on regional industry chains.

Lastly, there may be opportunities for some industry chains for further opening-up as the WTO and PTAs put pressure on each other and jointly drive the continuous evolution of international trade rules. The WTO tends to seek greater depth through innovation of mechanisms such as OPAs, while PTAs seek greater influence through the "extension" of rules. The interaction between the two may promote the opening-up and development of some industry chains, especially global necessities or emerging industries with no well-established rules in place, e.g., the aforementioned TRIPS waiver decision for COVID-19 vaccines authorizing developing countries to produce and export COVID-19 vaccines to other developing countries without the patent owners' consent.[33] In addition, driven by PTAs, some provisions have been gradually introduced in areas such as the digital economy and green economy, boding well for opening-up in these areas. For example, before 2020, there was considerable disparity among countries on digital taxes, and countries generally imposed unilateral taxes on digital companies, triggering trade protectionism. After multilateral organizations such as the G7 and the OECD came to an agreement with an approach to taxing the digital economy and set the minimum tax threshold for multinational companies at 15%, this agreement has gradually gained support under multilateral rules. We think this bodes well for improving the operation of the digital industry chains.

4.3.2 Impacts on Different Industrial Sectors Could Also Vary Notably

The evolution of trade rules impacts industry chains mainly through two channels—trade cost and production cost, and different industries may be affected and impacted to varying degrees due to different levels of sensitivity. We select four industries—i.e., textile & clothing, machinery manufacturing, electronic information, and coal & oil—to represent labor-, capital-, technology-, and resource-intensive industries, and analyze the differentiated impacts of the evolution of trade rules on different industries. Overall, "shallow" rules such as tariffs have a relatively large impact on

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[32] Crowley, Meredith A., and Lu Han. "The pro-competitive effects of trade agreements." (2022).

[33] LU Xiankun. "A New Beginning for the World Trade Organization." *International Economic Review* 5(2022):10.

labor-intensive industry chains such as textiles and apparel. Capital- and technology-intensive industries such as machinery and electronics are more susceptible to non-tariff barriers, implying that they could be more severely affected by the evolution of trade rules. The energy industry may also face higher trade risks due to its inherent characteristics and important influence on the economy.

As textiles and apparel is a typical labor-intensive industry, cost is at the core of its development, and the industry features limited intermediate inputs, relatively mature technologies, and high susceptibility to shallow trade rules such as tariffs. In retrospect, the Multifiber Arrangement (MFA) in the 1970s stipulated the proportion of textile and apparel exports of various countries in the form of quotas, which forced late movers to upgrade their industries. PTAs such as NAFTA, the African Growth and Opportunity Act (AGOA), and the Dominican Republic-Central American Free Trade Agreement (CAFTA-DR) strengthened regional textiles and apparel industry chains, and promoted the development of the textiles and apparel industries in East Asia and Southeast Asia, which now constitute the main hub of the textiles and apparel industry.[34] At present, although the textiles and apparel industry chain is relatively unstable and vulnerable to direct trade policies such as tariffs, it shows higher resilience than other industries in terms of its ability to recover from trade shocks.

In contrast, capital- and technology-intensive industries such as machinery and electronics are mainly subject to constraints from non-tariff barriers and may face more challenges. Capital- and technology-intensive industries are often characterized by high product complexity, abundant intermediate inputs, and strong economies of scale, and have formed relatively complex global production networks. Taking the chip industry chain as an example, major countries in Europe, the US, and the Asia–Pacific region all produce some key intermediate products, leading to autonomous and controllable risks for various countries. In the context of deglobalization, these industries may face more trade barriers. For example, some countries have disrupted global industry chains and accelerated the localization of so-called key products through trade protectionist measures such as export controls. As political factors and industry chain security become increasingly important, these two types of industries may be more severely affected by adjusted trade rules. This could manifest itself in an accelerated return of industry chains to their home countries and reduced cooperation across regions.

Although the impact of trade rules on the energy industry are relatively limited, the industry plays an important role in competition among great powers given its significant influence on the economic system; this could magnify the challenges and risks faced by the industry. Unlike the other three types of industries, the energy industry has been less affected by trade rules in the past, with both tariff and non-tariff barriers having a limited impact. Energy industry considerations may not be

[34] Gereffi, Gary, Hyun-Chin Lim, and Joonkoo Lee. "Trade policies, firm strategies, and adaptive reconfigurations of global value chains." *Journal of International Business Policy* 4.4 (2021): 506–522.

a main factor when countries sign PTAs.[35] However, the energy industry is highly dependent on geography, and it is vital to economic development (especially against the backdrop of the European energy crisis triggered by the Russia-Ukraine conflict). This means that the potential impact from geopolitics and competition among major countries on the energy industry cannot be ignored.

4.4 China's Trade Rules: Progress and Shortcomings

In retrospect, the multilateral trade system facilitated the rapid development of China's industry chains. Since its accession to the WTO, China has played an increasingly important role in international trade and coordination of production. It has become more deeply involved in the global division of labor. After 2001, China's global value chain (GVC) trade rose rapidly, having recorded an average annual growth rate of 27.3% before the 2008 financial crisis. Although the growth rate has slowed since 2010, the overall upward trend has remained intact. China's backward GVC participation[36] has declined, indicating falling reliance on imported intermediate goods and a rising position in the global value chain. This reflects China's efforts to attract capital and improve technologies to gradually replace foreign products in upstream and midstream markets with domestically-produced ones, while opening its domestic market to the world.

Looking ahead, China's industry chains face new opportunities and challenges. Bottlenecks faced by the WTO and an increase in trade frictions should accelerate the restructuring of industry chains in the Asia–Pacific region. As a major destination for offshore outsourcing, China's share of global trade in intermediate goods has been increasing over the past 20 years, having peaked at 10.3% in exports and 10.1% in imports in 2015. However, in recent years, the level of tariffs faced by China's goods exports has rebounded amid trade frictions, and corporate trade costs and industry chain risks in China have also increased. Such a change has driven the relocation of industries (the textiles and apparel, electronics, etc.) industries from China to Southeast Asia and India as these regions feature lower factor costs and are less affected by developed countries' tariff policies.

At present, we think China's trade rule system is yet to support the efficient and safe development of industry chains. First, China's influence is relatively modest in the multilateral system, and the country is not fully familiar with the application of international economic and trade rules. Since 2001, China has only filed 22 dispute cases with the WTO up to 2022, accounting for less than half of the cases filed against it, and most were cases against the anti-dumping and countervailing duties

[35] Galkin, Philipp, and Carlo Andrea Bollino. *The Effect of Preferential Trade Agreements on Energy Trade from Chinese and Exporters' Perspectives.* No. ks-2017—dp010. 2017.

[36] Backward GVC participation refers to the ratio of foreign value-added content (FVA) to a country's exports, and forward GVC participation refers to the ratio of domestic value added sent to third economies (DVX) to the economy's total gross exports. GVC trade = FVA + DVX.

imposed by developed members against Chinese exports. In comparison, the US has filed 124 dispute cases since 1996, accounting for 80% of the total number of the cases filed against the country.[37] We see this as evidence that China is not using multilateral trade rules to effectively deal with disputes initiated by developed countries. Developed countries have instead used these trade rules to justify their unilateral sanctions against China.

Second, China's regional trade agreements still have room for improvement in terms of contracting parties, depth of rules, and level of openness. First, China signed PTAs[38] mostly with Asian countries and developing countries, and economic factors often give way to diplomatic considerations in the choice of contracting parties.[39] Second, China's PTAs generally feature narrow coverage and shallow contents. For example, China's bilateral free trade agreements usually focus on market access and tariff reduction, while there is a lack of behind-the-border measures such as policy cooperation and dispute settlement. China's RCEP mainly focuses on traditional topics such as trade in goods and investment facilitation, with no significant progress made on the basis of the WTO framework.[40] In addition, the Belt and Road Initiative is based on "soft rules" such as memorandums of understanding (MOU), which have weak legal effect. China also has room for improvement in terms of the level of openness of trade agreements. For example, according to the China–South Korea Free Trade Agreement, the tariffs of 90% of goods will eventually be reduced to zero within a transition period of 20 years. In contrast, pursuant to the US-South Korea FTA, 95% of bilateral trade in consumer and industrial products would become duty free, with a transition period of no more than five years.

Third, China's domestic market still needs to be improved to support the development of a high-level trade system. The level of openness still needs to be improved—e.g., by enhancing service trade and investment liberalization—and issues related to SOEs, technology transfer, and industrial subsidies have yet to be fully resolved. Issues with the domestic market have restricted China's ability to align itself with and formulate high-standard international economic and trade rules, thus exacerbating issues faced by China such as the lack of voice in the multilateral system and the low complexity of its regional trade agreements.

International trade rules and global industry chains are undergoing a new round of reshaping amid deglobalization, presenting both new opportunities and challenges for China. Against such a background, a favorable international environment and trade partnerships can help stabilize corporate expectations, drive effective resource allocation, and increase the level of security and efficiency of industry chains. In view of these developments, we think China can actively participate in the reform of the

[37] Data as of October 31, 2022.

[38] Except for the Asia-Pacific trade agreement, PTAs signed by China are all in the form of a free trade area (FTA) (see footnote 1 in this chapter). The following discussions on China's PTAs refer to free trade agreements signed by China, including bilateral free trade agreements and RCEP.

[39] ZENG Ka. "China's free trade agreement diplomacy." *The Chinese Journal of International Politics* 9.3 (2016): 277–305.

[40] QUAN Yi. "A comparison of framework and rules between CPTPP and RCEP agreements." *Fujian Forum (Humanities and Social Sciences Edition)*5(2022):13.

WTO and drive multilateral cooperation platforms to keep pace with the times, adopt a multi-level development strategy to upgrade the level of regional trade agreements, and advance high-standard institutional opening-up using pilot free trade zones. The goal would be to create a concentric circle of multilateral, regional, and domestic markets, and establish a new system for a higher-level open economy.

Chapter 5
Digital Innovation Reshaping Industry Chains

Abstract Digital technologies have had profound and far-reaching impacts on the global economy in the past three decades. They have facilitated the digitalization of trade, and the optimization and restructuring of global industry chains. With data and information as the core factors of production, the digital revolution driven by technological innovation has given rise to new industries, and fostered the restructuring of global industry chains via the improvement of information communication and logistics infrastructure.

Digital technologies have reshaped existing resource endowments and comparative advantages. First, data has become a new core factor of production and an essential means of production (i.e., the "new oil"). Data is characterized by its near-zero marginal cost, replicability, and non-rivalrous nature. Unlike traditional factors of production, the transmission of data is no longer restricted by time or space.

Second, emerging technologies such as automation, artificial intelligence (AI), and the internet, as well as the rise of digital platforms, have transformed factors of production, and physical distance has become less important in the organization of industry chains. Digitization has therefore fostered more decentralized production and a more complex industry chain structure. In addition, the economies of scale and economies of scope for large economies are crucial for the development of the digital economy and industry chains. The US and China have leveraged their economies of scale to become giants in the digital economy, enabling digital platforms to increase user traffic and harness the full potential of their network effects.

Comparative advantages and resource endowments remain important for the distribution of global industry chains in the digital era. However, digital technologies are reshaping the traditional comparative advantages among major economies. The emergence of new markets, demand, and technologies are driving the development of new products and new industries. Technologies such as AI, blockchain, cloud computing, and new forms of organization for production and trade such as digital platforms are changing trade patterns while reducing logistics costs and improving

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production efficiency at the same time. The global industry chains are also undergoing profound changes in the process of digitalization.

Geopolitical tensions and COVID-19 conditions have brought disruptions and uncertainties to global industry chains. Economic restructuring in the digital era brings new challenges and opportunities to upgrade and restructure industry chains. Amid intensifying digital competition, major economies are introducing new policies and measures to facilitate economic digitalization, and build or consolidate advantages in digital industries and trade.

Under complex international trade conditions, we think China can fully leverage the economies of scale for a large country, encourage technological innovation, foster new markets, strengthen the digital industry chain, and facilitate the digitalization of China's industry chains. In our view, China can enhance its digital and data security while also encouraging data flows and the growth of digital markets and economies. By improving the management of data and digital platforms and deepening digitalization, China is poised to boost the efficiency and optimize the structure of its industry chains.

Keywords Digital innovation · Industry chain security · Government support

Digital technologies have had a profound impact on the global economy over the past three decades, and have significantly facilitated the structural upgrading of global industry chains, on their regional transfer, as well as on their adjustments. While China's traditional economy (offline economy) is under pressure from global COVID-19 conditions, geopolitics, and competition from large countries, its digital industry is still developing rapidly, and digitalization and digital security are becoming increasingly important in global industrial competition.

However, the development of China's digital economy and industry still faces numerous challenges such as intensifying global competition in technologies, data, and digital platform governance. How China competes globally by leveraging its core advantages, including its scale, while ensuring the security of its industry chains is a key issue.

5.1 Important Factors of Industry Chain Reform in Technological Innovation

The digital era has brought about new markets, demand, and productive forces, and data has become a new core factor of production. This further affects the resource endowment and comparative advantages of various economies. The zero marginal cost of data and the significantly weakening importance of physical distance in the platform economy are conducive to the regional diversification of production and trade. Economies of scale and economies of scope have become more prominent in the digital era than in industrial era: The platform model in the digital economy relies on massive data, user traffic, and network effects to reduce costs and improve efficiency. Amid deglobalization and competition among large countries, the economies of scale for a large country provide important support to the security and efficiency of industry chains in the digital economy.

In the digital era, data has become a new core factor of production[1] **and an essential means of production (i.e., the "new oil"), but it differs from traditional factors of production. First, data has diverse sources of value.** Both raw data and corporate efforts to collect, store, and analyze data are indispensable. **Second, data is replicable and non-rivalrous**.[2] A rise in the number of users neither weighs on the quality and supply of data, nor does it affect its use by other users. Information sharing and its free flows can generate greater value.

However, there is a lack of motivation to share data due to market competition and the cost of acquiring and processing data. In addition, national security could be compromised when it comes to cross-border data flows. As a result, the governance, production, and use of data differ sharply from traditional factors of production. To facilitate data use, it is important to determine proper data ownership, protect the interests and privacy of data owners, and ensure secure and efficient cross-border data flows. **Major global economies attach great importance to data. China has gained certain advantages in underlying data resources** thanks to its large population and the sizeable user base of its internet platforms.

Data infrastructure is crucial for the development of industry chains. Declining cost and significant improvement in the capabilities of data collection, storage, and computing hold the key to the development of big-data application technologies. According to the *Global Computing Index Assessment Report (2020)*,[3] a 1ppt increase in the computing power index can boost the digital economy and GDP by 3.3‰ and 1.8‰ on average. The efficiency of data storage and computing has improved significantly since Amazon launched its cloud computing services in 2006. Developed countries remain dominant in cloud data.

China has built 5 mn standard server racks. Its computing power has reached 130EFLOPS,[4] and the demand for computing power is growing rapidly. Data centers in China are mainly located in the resource-tight eastern regions. Meanwhile, western China boasts rich resources such as renewable energy, and enjoys comparative advantages in large-scale development of data centers catering to computing demand in eastern regions.

In February 2022, the National Development and Reform Commission (NDRC) and other regulators launched the "east data, west computing" initiative to build

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[1] Varian, Hal R. *Artificial intelligence, economics, and industrial organization.* Vol. 24839. Cambridge, MA, USA:: National Bureau of Economic Research, 2018.

[2] Moody, Daniel L., and Peter Walsh. "Measuring the Value Of Information-An Asset Valuation Approach." *ECIS*. 1999.

[3] IDC, IEIT Sysstems, and Tsinghua Institute for Global Industry. The 2020 Global Computing Index Assessment Report. February 2021.

[4] https://www.gov.cn/zhengce/2022-02/17/content_5674343.htm [Chinese only].

national computing hubs in the Beijing-Tianjin-Hebei region, Yangtze River Delta region, Guangdong-Hong Kong-Macao Greater Bay Area, Chengdu, Chongqing, Inner Mongolia, Guizhou, Gansu, and Ningxia, with plans for 10 national data center clusters. By developing an integrated computing network of data centers, cloud computing, and big data, the initiative takes full advantage of western China's rich computing resources to meet data computing demand in eastern China, thus facilitating the digitalization of industry chains.

The large-scale use of data has also brought about some new challenges which impede the efficient use of data in a secure environment. First, illegal data collection and use, data leakage, and insufficient privacy protection pose challenges to the use of data. For example, some data companies take advantage of crawler software to illegally scrape data from internet platforms. In September 2019, big data companies were investigated for their illegal data scraping businesses.[5] Starting in November 2019, the Ministry of Public Security cracked down on mobile applications' illegal collection of personal data, and shut down more than 100 mobile applications.[6] However, legal and appropriate data scraping helps address problems such as data islands.

In addition, core data has the potential to significantly impact national and corporate security. Therefore, it has become an increasingly important target of competition among large countries. The leakage of core data can have far-reaching impacts on key industry chains. For example, in September 2021, the US Department of Commerce[7] asked major silicon chip producers, including TSMC and Samsung, to voluntarily share key supply-chain information, such as orders, inventories, and sales. This information, often seen as highly confidential, was sought to enhance transparency within the supply chain. The Department also hinted at the possible use of the Defense Production Act to mandate the sharing of data if necessary. Such data can help US companies maintain competitive advantages, adjust their industrial plans based on global supply and demand conditions of silicon chips, and improve their key position in the global industry chain of silicon chips.

Automation (including the use of robots) helps mitigate the impacts of contraction of the labor force caused by population aging. Automation before the digital era boosted labor productivity and resulted in the reallocation of employment across industries and the aggregate fall in the labor share.[8] Automation and artificial intelligence (AI) have the potential to reduce the labor intensity of certain industry chains, decrease the importance of cheap labor as a comparative advantage, and possibly replace human labor in more complex jobs that require cognitive judgment in the

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[5] http://capital.people.com.cn/n1/2019/1101/c405954-31432388.html [Chinese only].

[6] http://m.news.cctv.com/2019/12/08/ARTIx7UFOLNLIExxenOFvSSe191208.shtml [Chinese only].

[7] https://www.bloomberg.com/news/articles/2021-09-23/white-house-weighs-invoking-defense-law-to-get-chip-supply-data#xj4y7vzkg

[8] Autor, David, and Anna Salomons. *Is automation labor-displacing? Productivity growth, employment, and the labor share*. No. w24871. National Bureau of Economic Research, 2018.

future.[9] However, the overall impact of automation and AI on the labor market remains unclear.[10] Automation and AI have not yet led to large-scale reshoring for the production of labor-intensive manufactured goods.[11]

However, the emergence and expansion of digital platforms, the sharing economy, the gig economy, and the increasing popularity of teleworking may affect the distribution of labor factors and the structure of industry chains. Jobs related to digital platforms and the gig economy typically require diverse skills and greater flexibility. The flexibility in working time and location helps optimize the allocation of labor resources. According to the International Labour Organization,[12] the sharing economy in China has attracted plenty of part-time workers and urban jobseekers that face difficulties in securing employment, and has acted a reservoir for the labor market.

According to a survey of digital platform workers in 2019,[13] about 50% of those surveyed had a bachelor's or higher degree, while more than 60% had retained the same income source they had before beginning to work on digital platforms and have thus added platform-based work to their income-earning activities. The popularity of teleworking based on digital technologies was boosted during the COVID-19 pandemic. In 2020, about 42% of the US workforce worked from home full-time and only 26% worked on-site,[14] while the number of traditional workers working as digital nomads grew 96% from about 3.2 mn to about 6.3 mn.[15] **Digital platforms, the sharing economy, the gig economy, and teleworking have effectively expanded the labor force, changed traditional working methods**, and empowered workers with different skills and educational levels to participate in the division of labor and cooperation. This bodes well for optimizing the allocation of factors of production such as labor, and for improving productivity.

Economies of scale have played a key role in various industrial revolutions. In the digital era and the platform economy, economies of scale and economies of scope hold the key to reducing costs and improving efficiency. Frontrunners in the digital revolution such as the US and China boast the largest markets and the highest number of internet users in the world. While the overall market of the EU is sizeable, it is also fragmented due to differences in institutional mechanisms, languages, and cultures. This weighs on the economies of scale of digital technologies and platforms.

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[9] Autor, David H. "Why are there still so many jobs? The history and future of workplace automation." *Journal of economic perspectives* 29.3 (2015): 3–30.

[10] Frank, Morgan R., et al. "Toward understanding the impact of artificial intelligence on labor." *Proceedings of the National Academy of Sciences* 116.14 (2019): 6531–6539. Fujiwara, Ippei, and Feng Zhu. "Robots and labour: implications for inflation dynamics." *BIS Paper* 111c (2020).

[11] UNCTAD. Robots and Industrialization in Developing Countries. 2016.

[12] ILO. Digital labour platforms and labour protection in China. 2020.

[13] ILO. Online digital labour platforms in China: Working conditions, policy issues and prospects. 2021.

[14] Bloom, Nicholas. "How working from home works out." *Stanford Institute for economic policy research* 8 (2020).

[15] MBO Partners. COVID-19 and the Rise of the Digital Nomad, State of Independence in America Report. 2020.

One of the contributors to the success of US digital platforms is their active integration into global markets and efforts to take full advantage of global markets and industrial scale. US platform companies have much higher overseas revenue exposure than their Chinese peers. For example, overseas revenue accounts for over half of total revenue at Google, Facebook, and eBay, while Alibaba Group's international revenue contribution is considerably lower, at 7% in 2021.[16] Due to lack of overseas experience, Chinese platform companies have not managed to effectively expand in overseas markets. Under deglobalization, China's large domestic market remains a major advantage for platform companies to grow. We believe these companies can leverage the enormous domestic market in China to expand their global presence and market share, which we believe will help further improve economies of scale.

The foremost focus of international competition in the digital era is strategically important digital innovations, such as AI, 5G, cloud computing, blockchain, and big data. As the world's biggest economy and a large technological power, the US is a pioneer in the development of core digital technologies and infrastructure, and remains a leader in a number of key areas thanks to its economies of scale. The country's abundant advanced human capital and technological resources are the cornerstone of its leadership of the global digital economy. The US leads in data analysis technologies, but China is working diligently to catch up.

Digital industries are the foundation of the new economy. Despite a relatively late start, China's digital industries are thriving on the back of the country's enormous market, strength in learning and incremental innovation, well-established manufacturing industries, and solid government support. We expect China to catch up with leading developed economies in digital infrastructure over the coming years, and think its strong telecom infrastructure will support digital transmission. China is already leading the world in the penetration rate of 5G, which is an accelerator of digital industries.

The economies of scale for large countries facilitate the development of digital industries, and provide important support for the digital economies of China and the US. For example, the US and China lead other economies in the public cloud market (Fig. 5.1) thanks to the sheer size of their economies. Cloud services tend to have high requirements for underlying architecture, and advanced digital infrastructure and underlying data are essential for the development of the cloud industry. The subscription-based and pay-per-use business model of cloud computing lowers the threshold for purchases and use, which is conducive to scaling up user base.[17]

The development of China's emerging technological industries such as internet of things (IoT) and virtual reality (VR) relies on cloud computing and 5G's low-latency and high-bandwidth data transmission capabilities. Substantial cloud-based computing drives the rapid development of the cloud industry from the demand side, and gives rise to strong cloud service companies such as Alibaba Cloud and

[16] Companies annual reports.

[17] CICC Research. The ethereal ascent—IaaS. 2021. [Chinese only].

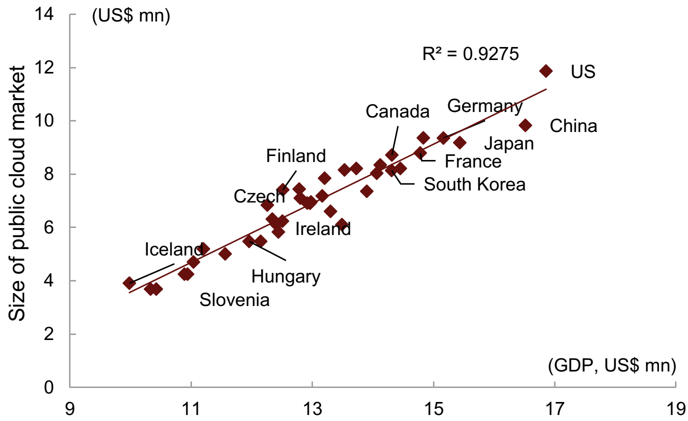

Fig. 5.1 China and the US enjoy economies of scale in the public cloud market (2020). *Note* Both horizontal and vertical axes are in US$ mn (in logs). *Source* Statista, Haver, CICC Global Institute

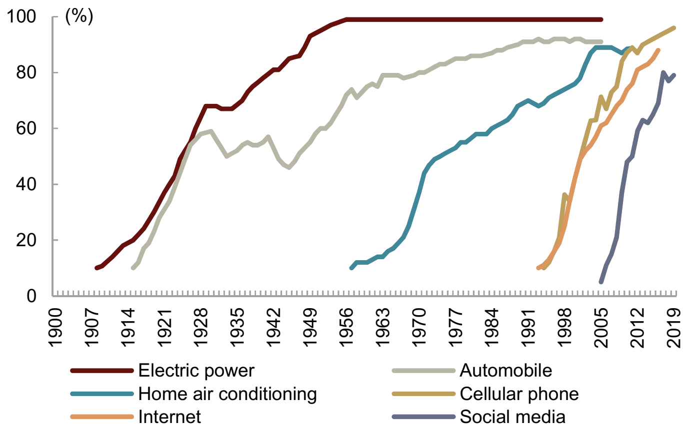

Fig. 5.2 The digital era typically involves a much shorter interval between the introduction of new technologies and their large-scale use. *Note* The percentage of US households using a particular technology. *Source* Our World in Data, CICC Global Institute

Tencent Cloud. For example, the public cloud market tripled from US$55.85bn to US$170.9bn over 2016–2021 in the US, and grew nearly sevenfold from US$3.84bn to US$26.09bn in China.[18]

Economies of scale are particularly important for industry chains amid the digital revolution. The interval between the introduction of major technological innovations and their large-scale application has shortened markedly (Fig. 5.2), and

[18] https://www.statista.com/outlook/tmo/public-cloud/worldwide#analyst-opinion

the importance of scale effect has shifted from hardware to software. **For digital platforms, user traffic represents their distribution channel, content is essentially marketing, and scale is a key contributor to the success of platform companies**.[19]

For example, content platforms such as Douyin, Kuaishou, and Xiaohongshu have leveraged their very high user traffic to venture into e-commerce retail, while live-streaming e-commerce has further boosted their user traffic and scale. In addition, WeChat Pay was largely marginalized at first as it could not scale up to expand its user base. It was not until 2015 that it quickly expanded into the electronic payment market by taking advantage of its existing social networks to allow users to send electronic red envelopes during the Spring Festival Gala. A total of 20 mn users sent or received red envelops on Wechat that night, and the number of red envelopes received and sent exceeded 1bn.[20] WeChat Pay has thus rapidly scaled up, significantly reducing costs and improving efficiency.

Non-e-commerce platforms are able to rapidly improve economies of scale in the e-commerce retail sector on the back of their enormous user base and traffic. This inclusiveness and user traffic facilitate the participation of various types of companies (especially small and micro ones) in the industry chain. For electronics manufacturing, China accounted for 37% and 24% of global exports and imports related to information and communication technologies in 2021.[21] For China, it is crucial to fully leverage the economies of scale and maintain competitive advantages to develop core digital economy applications such as digital platforms and industrial internet. In addition, economies of scale in the digital industry itself can effectively foster China's economic development, as well as digital transformation and upgrading of its industry chains.

5.2 Technological Innovation Reshapes Economy and Industry Chains

Technological innovation is an important engine for industrial development, and a core driving force for the formation and development of industry chains. In addition to mitigating inefficient and costly industry chains, large-scale technological innovations are also inclined to give rise to new industry chains and support their sustained development.

Digital innovations encourage the development of new products and the rise of numerous smart products and new industry chains that are characterized by the collection and transmission of data through the internet. More and more companies are applying new technologies to traditional products to increase product value and

[19] CICC Research. Digital empowerment: The future of industrial digitization has come. 2020. [Chinese only].

[20] https://www.sohu.com/a/447226173_223323

[21] Calculated based on data from UNCTAD.

generate new revenue.[22] For example, software, computing power, and sensors are crucial for the automobile industry in the digital era. Automobiles have also become increasingly complex amid the rising importance of electronics and software. The software lines of code (SLOC) for automobiles rose significantly from about 10 mn lines in 2010 to about 150 mn lines in 2016. Automobiles are gradually transitioning from hardware-defined to software-defined.[23]

Technological innovations tend to reshape traditional service models and create new services. Traditional offline industry chains such as catering, culture & entertainment, tourism, and payment services are migrating online.[24] Data shows that online ride-hailing accounts for approximately 40% of global ride-hailing market revenue in 2021, and the online market may grow rapidly at a CAGR of 13.1% over 2022–2028.[25] The revenue of Didi, Uber, and Lyft rose by 31%, 57%, and 36% YoY to about US$26.95bn, US$17.46bn, and US$3.21bn in 2021.

The music industry is also transitioning from records and tapes to streaming, and music services such as online streaming have grown rapidly in the past decade (Fig. 5.3). For example, Spotify's MAU and paying subscribers more than doubled over 2016–2021.[26] The structure of industry chains has changed drastically in some industries that are more affected by digitalization. For example, the e-commerce business has expanded rapidly, especially in Asia.

The industrial revolution led by digital technologies has led to changes in the organization of production and trade. **Digital platforms** have risen and played an increasingly important role in the division of labor and restructuring of industry chains. Platform companies have grown rapidly over the past 20 years. They accounted for five of the 10 largest listed companies in the US and Hong Kong stock markets (by market value) in 2015 and seven in 2020.[27] However, the operation and expansion of digital platforms have also posed some challenges, especially regarding market competition and the protection of investor and consumer rights.

Effective regulation and platform governance are important for the healthy development of platform companies. In recent years, China and the US have made inroads in strengthening regulation of platform companies and platform governance. However, the new features of digital platforms have also resulted in some new challenges. First, digital platforms are essentially information intermediaries backed by new technologies. They enjoy significant network effects, economies of scale, and economies of scope, and large scale and enormous data form the cornerstone of their success.

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[22] PwC. The fourth industrial revolution: a recovery plan for today's economic storm. 2020.

[23] McKinsey. Rethinking car software and electronics architecture. 2018.

[24] Schwab, Klaus. *The fourth industrial revolution.* Crown Currency, 2017.

[25] Grand View Research. Ride-hailing And Taxi Market Size, Share & Trends Analysis Report By Type (Ride-hailing, Taxi), By Distribution Channel, By Region, and Segment Forecasts, 2022 - 2028.

[26] Spotify annual reports.

[27] Calculated based on data from iFIND.

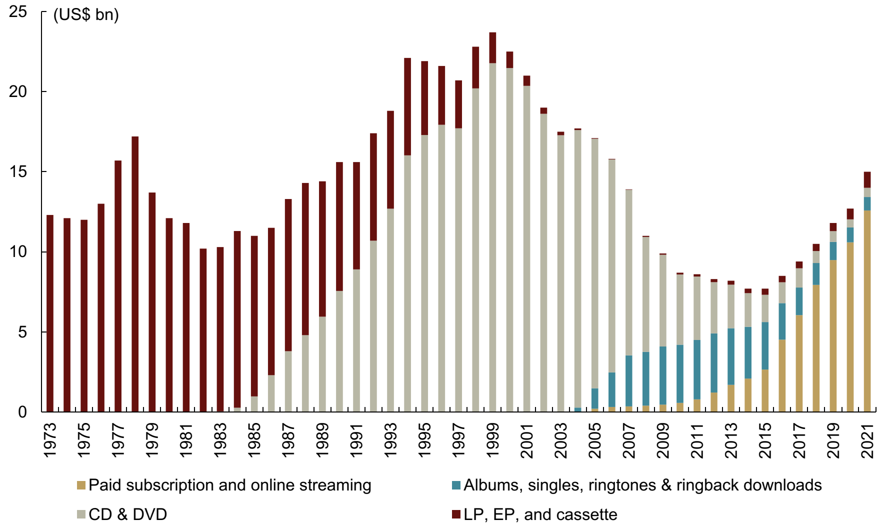

Fig. 5.3 Music industry transitioning from records and tapes to streaming. *Note* US music industry revenue by format (US$ bn in 2021 dollars), 1973–2021. *Source* RIAA, CICC Global Institute

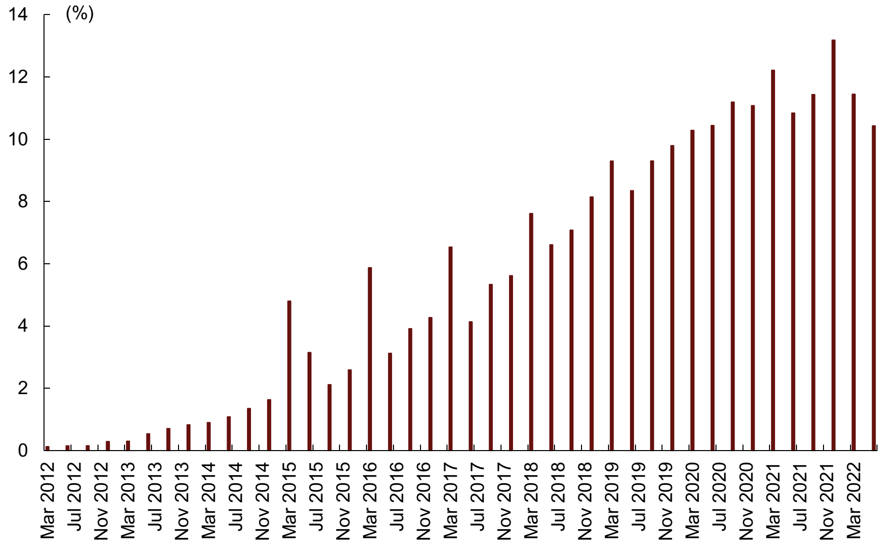

Fig. 5.4 Limited market share for Alipay and WeChat Pay in payment market. *Note* Percentage of mobile payment in total amount of non-cash payment business. *Source* Wind, CICC Global Institute

We should take into account various factors to assess whether a platform company is monopolistic, including the definition of the market in question. While Alipay and WeChat Pay accounted for more than 90% of the third-party mobile payment market in 2020, mobile payment accounted for about 10% of the total non-cash payment business (Fig. 5.4), and the market share for small-amount payment was even lower. The market share of Alipay and WeChat Pay remained well below that of banks and credit card issuers. In addition, large digital platforms usually operate in multiple markets, and related markets should also be taken into account when assessing monopolistic practices.

Moreover, it is difficult to assess whether digital platforms seek market dominance by offering products and services at below-cost prices. For example, search engines such as Google and Baidu, entertainment platforms such as Netflix and Spotify, and social networking platforms such as WeChat tend to provide their services for free or at low prices below marginal cost.[28] The reason is that the low marginal cost and multilateral market nature of their products and services enable digital platforms to provide high-quality services to users at low cost, and their main revenue comes from fees levied on merchants operating on their platform or other related markets.

Digital technology innovations have had a far-reaching and profound impact on the distribution and organizational structure of global industry chains (Table 5.1). **The digital revolution has given rise to new core factors of production such as data and changed some traditional factors of production,** thus reshaping the resource endowments and comparative advantages of different economies and the global distribution of industries. **Thanks to the near-zero marginal cost and network effect of digital technologies and platform services,** countries with large economies and internet sectors enjoy advantages in the development of digital industries and the digital transformation of traditional industries.

The platform organizational model guides the complex division of work location and value creation. Digital platforms make it possible to distribute work across different regions on a large scale, and workers in low-income countries benefit from participating in the online labor market. In addition, instead of establishing overseas branches, companies can optimize global production and distribution through platforms and big data analysis. The platform model lowers the cost of search and matching, and allows small and micro enterprises in different regions to reach clients and integrate into the large market.

New industries of the digital economy tend to be more reliant on specific resources, which drives dynamic adjustments of comparative advantages for different economies. For example, cloud computing and cryptocurrency mining

[28] Strowel, Alain, and Wouter Vergote. "Digital platforms: To regulate or not to regulate? Message to regulators: Fix the economics first, then focus on the right regulation." (2018).

Table 5.1 Digitalization affects international division of labor and trade and reshapes industry chains. *Source* WTO (2018),[29] Deardorff (2017), CICC Global Institute

Major impact	Specific impact	Core digital technology and application	Impact of industry chain layout
Reducing trade costs	Transportation, logistics, warehousing costs	AI, self-driving, intelligent robot, 3D printing	Promoting exports, encouraging greater participation of small and medium-sized enterprises in international trade; promoting vertical decentralization of production; weakening local market size advantage, changing the location of industrial agglomeration
	Cross-border, customs compliance costs	Blockchain, AI	Enhancing the trade of time-sensitive (life-saving medical), certification-intensive (luxury goods, food), and contract-intensive goods (professional scientific equipment).
	Information and transaction costs	Online platforms, IoT, blockchain, real-time translation	Promoting offshore production conducted in the form of outsourcing (contract-intensive); market size expands for individuals and small businesses.
	Cost of cross-border payment and financial services	Online platforms, mobile banking, blockchain	Encouraging the participation of small and medium-sized enterprises in international trade
Reducing the costs of FDI	Construction and operating costs	Industrial Internet Platform, AI, PaaS	Promoting offshore production in the form of FDI
Enhancing production efficiency	Increase of labor efficiency and TFP	IoT, intelligent robots, AI, big data, cloud computing	Facilitating enterprises shift from local sourcing to global sourcing (outsourcing) and transnational operations (FDI)

(continued)

[29] WTO. The future of world trade: How digital technologies are transforming global commerce. 2018.

Table 5.1 (continued)

Major impact	Specific impact	Core digital technology and application	Impact of industry chain layout
Enlarging the divergence in efficiency within the industry	Market structure of the industry	Platform, big data, cloud computing, AI, IoT	The digitalization with its high fixed-costs and low variable costs characteristics amplifies the role of economies of scale, giving rise to a pattern of large enterprises and monopolistic competition. Simultaneously, the platform economy leads to an increase in small and micro-business operators, widening the efficiency gap within the industry, which makes FDI more likely to occur
Changing the factor intensity of the industry	Labor, technology, and energy intensity	AI, intelligent robots, cloud computing	Digital technology's nature of artificial substitution renders it akin to capital, altering the labor-intensive attributes of certain industries, and weakening the comparative advantage of low labor costs in developing countries. Cloud services are both energy-intensive and technology-intensive, complicating comparative advantages
Changing the importance of design and research	R&D and technology intensity	AI, digital twin, big data	Reducing R&D costs while enhancing the importance of R&D, increasing the headquarter service intensity in certain industries, promoting vertical integration rather than outsourcing
Generating new products	Service digitalization, product softwarization	Telepresence, medical tele-robot	Increasing the share of service trade in global trade, countries with comparative advantages in the provision of certain services can have larger markets
Promoting new synergies	New business models: Platforms, sharing, gig economy	Platforms, AI, big data, intelligent algorithms	Promoting exports and the entry of small and micro enterprises into the market. In the initial stages of development, market size is crucial, with scale replacing factor endowments determining a country's ability to export platform services

(continued)

Table 5.1 (continued)

Major impact	Specific impact	Core digital technology and application	Impact of industry chain layout
	New production models: From mass production to flexible, customized production	IoT, data analysis, equipment intelligence	While meeting personalized demands, maintaining production efficiency and solidifying the existing industrial distribution pattern at the same time. On the other hand, highly customized demand weakens the advantage of industrial agglomeration, prompting production to move closer to end consumers
	New customer relationships: Platform-based, bidirectional, community-oriented, personalized services	Platforms, AI, big data, intelligent algorithms	Enabling small businesses to offer products and services directly to users, mitigating the impact of trade barriers

require substantial amounts of cheap energy,[30] and the production of smart cars depends on resources such as lithium, cobalt, and nickel. In addition, economies with abundant human capital with expertise in AI and big data may also have advantages.

In addition, digital technologies reduce trading costs and improve corporate efficiency. Digital technologies in transportation and warehousing help reduce logistics costs. Digitalization also facilitates cross-regional and cross-border trade in services such as education and healthcare, and markedly lowers barriers to trade and costs for certain services. As a result, some economies may gain new comparative advantages or strengthen their traditional comparative edges. Digital technologies such as blockchain and smart contracts foster trust, reduce transaction costs, and facilitate contracts, boding well for the development of contract-intensive industries. Non-economic factors, including political ones, may also have a decisive impact on the formation and reshaping of industry chains.

Service sectors have become much more tradable in the era of the digital economy**.** Digital technologies have markedly cut the cost of international communication, and large platform companies have made long-distance services more feasible and convenient. For the time being, companies still mainly rely on overseas branches to facilitate cross-border service trade. However, along with the further digitalization

[30] Deardorff, Alan V. "Comparative advantage in digital trade." *Cloth for Wine?* (2017): 35. Deardorff discussed the resource endowments of Iceland for the cloud computing industry. The country boasts rich geothermal and hydropower resources, and nearly all of its electricity is produced from clean energies. Meanwhile, the concentration rate of the global cloud computing sector is high, with Google, Microsoft and Amazon controlling about 2/3 of the global market. These companies pledge for carbon neutrality makes Iceland an attractive country for building cloud computing centers.

of the economy, remote service provision on the back of digital technologies may become increasingly popular. This should expand the varieties of tradable services.

However, according to the United Nations Conference on Trade and Development, while the value of digitally-delivered trade in services continued to grow between 2006 and 2020 and exceeded US$3trn in 2020, about 90% of the services were provided by high-income or high-and-middle-income economies. The digital divide may hinder low-income economies from benefiting from this new trade model.

The global structure of industry chains has changed drastically in some industries, and regions with economies of scale have become home to the digital industry chains. For example, nearly US$1.8trn of global digital platform revenue (US$3.8trn) was generated in Asia in 2019, and most B2B e-commerce platforms are headquartered in Asia, followed by North America and Europe.[31] However, digitalization has not resulted in large-scale changes in the structure of industry chains for sectors such as pharmaceuticals, textiles & apparel, home appliances, equipment manufacturing, photovoltaics, and lithium-ion batteries. That said, a growing number of Chinese firms from these sectors are expanding overseas, especially in R&D, maintenance, sales, and production & assembly.

Digital technologies make it efficient and cost-effective for companies to expand overseas. For example, they enhance computing power to facilitate R&D, and reduce labor use and operating costs on the back office end on the back of ERP, SaaS, and PaaS. They also lower the cost of machine debugging, operation, and maintenance via industrial internet. In addition, digital technologies reduce the fixed costs of offshore operations, and leverage overseas endowments such as lower labor and land costs in emerging economies, and the advantages of Europe and the US in skills, contracts, and institutional quality. This is conducive to improving profitability and competitiveness.

Current digital technologies are unable to support reshoring for the time being. While digital technologies can reduce a variety of fixed costs in foreign direct investment (FDI), they are less effective at compensating for the developing countries' lower labor costs in many industries. Empirical studies have not found notable signs of reshoring so far. According to the Congressional Research Service (CRS), the cost reduction from automation does not make a compelling business case for reshoring in the textiles & apparel sector. For example, Adidas opened two robotic "Speedfactories" in Europe and in the US in 2016 and 2017, respectively, in an attempt to leverage 3D printing technologies to reduce reliance on human workers and shorten production time. However, the firm relocated its factories back to Asia after a few years. Similarly, Nike has long been relying on a large network of contract manufacturers.[32]

[31] ADB. Asian Economic Integration Report 2021.

[32] CRS. Global Value Chains: Overview and Issues for Congress. 2020.

5.3 New Economy and New Industrial Policies

The digital economy's contribution to the global economy is increasing, and has become an important engine of global economic growth. We believe China can actively foster the development of the digital economy, as well as the digital transformation and upgrading of industry chains, to cope with the pressure and challenges from non-economic factors on China's development and on upgrading global industry chains.

The global economy and industry chains are facing the most severe challenges since the Second World War. While COVID-19 and geopolitics weigh on the security and stability of global industry chains, they have also given rise to new development opportunities for the digital economy. The emergency response of various countries to COVID-19 has put unprecedented pressure on logistics, production and trade. However, this has also facilitated the development of the digital economy, and accelerated the digital transformation and intelligent upgrading of traditional industries. The proportion of global service trade rose rapidly during the pandemic, and the platform economy and e-commerce have trended upwards. In addition, China has strengthened its advantages in electronics manufacturing industries, which are an important part of digital economy infrastructure.

Various countries are attaching high importance to industry chain security, and the development of China's digital economy faces challenges from both internal and external environments. First, China is subject to external constraints on core technologies for digital industries. Second, restrictions on digital trade and investment in various countries have increased significantly.

Amid deglobalization and growing international geopolitical tensions, **major economies have moved quickly to introduce and implement strategies promoting development of the digital economy and digital industries.** The number of policy documents on cutting-edge digital industries introduced by major countries in 2021 was about 1.5 times that of 2017.[33] **Developed economies attach great importance to improving the core competitiveness of digital industry chains and accelerating their localization and diversification.** In March 2021, the EU released *2030 Digital Compass: the European way for the Digital Decade*. The document proposed that the production of cutting-edge and sustainable semiconductors in Europe, including processors, should be at least 20% of world production in value by 2030. In May 2021, the EU unveiled a supply chain diversification plan aimed at reducing its reliance on overseas suppliers in six strategic areas, including semiconductors, raw materials, and active pharmaceutical ingredients.

Government support has played an important role in facilitating the development of advanced technologies such as digital technologies. The US Defense Advanced Research Projects Agency (DARPA) began to attach importance to AI technologies and conduct related research ever since the 1960s. Considering the threat from Japan, the US provided US$1bn in funding for the development of advanced

[33] China Academy of Information and Communications Technology. Report of global digital industry strategies and policies. December 2021. [Chinese only].

computer hardware and AI technologies through the Strategic Computing Initiative (SCI) in 1983–1993.[34] AI technologies developed rapidly in the US supported by the SCI, with the development of technologies such as the Autonomous Land Vehicle project and its sister project Navlab. They provided a technological foundation for autonomous driving. In 1986, the US and Japan signed the *US-Japan Semiconductor Agreement*, in which Japan agreed to limit the exports of semiconductors. In 1987, the US government and a number of US-based semiconductor manufacturers formed the Semiconductor Manufacturing Technology (SEMATECH) consortium to provide member companies with R&D resources, share research results, and improve efficiency in innovation.

In recent years, major economies have increased investment in technological innovation. Data from Eurostat shows that companies in the information and communication technology (ICT) industry account for 39.9% of the world's top 2,500 companies in R&D spending in 2021. The *CHIPS and Science Act* involves a total investment of more than US$280bn, including: 1) US$52.7bn in subsidies for US silicon chip manufacturing, R&D and workforce development; 2) a 25% investment tax credit for companies that set up silicon chip factories in the US; and 3) about US$200bn for fostering innovation in areas such as AI and quantum computing. The European Commission also plans to invest EUR1.98bn via the Digital Europe Program, with a focus on AI, cloud data space, and quantum communication infrastructure, among others.[35]

Major economies have also taken various measures to encourage and support corporate R&D investment. The EU and the US allocate a similar percentage of government spending to R&D, but R&D spending in the commercial sector as a percentage of GDP in the US is much higher than that in the EU. In the US, the corporate sector is the largest contributor to R&D investment. For high-tech startups, the amount of venture capital investment increased from US$2.59bn in 1985 to US$130.92bn in 2018.[36] Notably, the amount invested in the software information industry remains the largest, accounting for more than 20% of the total. In the early stage of internet commercialization in the US, venture capital investment in the country grew rapidly, giving rise to well-known names such as Google and Yahoo. Since 2000, China's corporate R&D spending as a percentage of GDP has risen markedly and is gradually approaching levels of corporate spending in the US.

Major economies are striving to establish an environment conducive to platform development. The platform economy is still growing and is being refined, and the effective regulation and governance of digital platforms remains a key research topic for regulators in various economies. The core aim of the US's digital

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[34] Roland, Alex, and Philip Shiman. *Strategic computing: DARPA and the quest for machine intelligence, 1983-1993*. MIT Press, 2002.

[35] https://ec.europa.eu/commission/presscorner/detail/en/ip_21_5863

[36] REN Zeping, LIAN Yixi, XIE Jiaqi. Global Internet Development Report 2019: Why the United States Dominates and China Rises?. 2021.

strategy is to consolidate its global competitiveness. The country focuses on forward-looking strategic deployment, digital industry development, R&D of advanced technologies, and digital transformation of the real economy, and emphasizes a free and open global digital market. However, the EU focuses on building a unified digital ecosystem, improving regulations for the digital economy, and enhancing regulations for privacy protection.

Meanwhile, there is a digital divide between the large number of developing countries and developed countries. Most developing countries do not have a mature digital governance mechanism in place, and their regulation and governance systems vary. Emerging market countries such as India, Brazil, and Indonesia take a more protectionist and conservative approach to digital governance in a bid to protect their domestic markets and maintain digital security. In some African and Middle Eastern countries, the proportion of the digital economy to their overall economies is low, and their governments have not formulated development strategies for the digital economy. In our view, digital governance has yet to attract the attention it is due in these countries given the growing significance of the digital economy, and overall regulation remains relatively relaxed.[37]

At the core of global digital governance is the trade-off between the free flow of data across borders and data localization. The US advocates information globalization characterized by the free flow of data, but the country does not relax control on important domestic data. It has banned the outflows of sensitive domestic data, includes foreign companies that store or collect sensitive personal data of US citizens in screening, restricts the entry of overseas digital companies in core fields into the US, and authorizes regulators to garner extraterritorial data through long-arm jurisdiction.

Meanwhile, the EU's General Data Protection Regulation (GDPR) emphasizes the secure cross-border management of personal data. It encourages the free flow of data within the EU, includes countries and regions that comply with the EU's data protection standards in their "white list",[38] and determines whether cross-border data flows are allowed through *ex-ante* regulations. China attaches high importance to data security. The Cybersecurity Law promulgated in 2017 requires operators of critical information infrastructure to store important data and personal information in China.

Emerging economies tend to restrict cross-border data flow, and aim to protect their domestic digital industries through data localization. However, the actual implementation of their data localization depends on the digital governance capabilities and on the dependence of their digital economies on foreign countries. For example, Vietnam requires multinational internet service companies to set up data centers there. **India, on the other hand, remains undecided on data localization.** In 2018

[37] ZHANG Monan. "Global digital governance: Differences, challenges, and China's strategies." *China Opening Journal* 6(2021):7. [Chinese only].

[38] A "white list" refers to a list of countries or territories that the EU considers able to provide an adequate level of data protection, which is essentially equivalent to the data protection offered within the EU itself. This determination is made by the European Commission.

and 2019, India introduced two versions of the Personal Data Protection Bill, which stipulated that sensitive and critical personal data must be stored in India, but the bill was withdrawn in August 2022.[39] The reason is that India is a hub for IT service exports, and it processes sensitive data in sectors such as healthcare and finance for other countries. The bill is highly likely to discourage overseas demand for Indian IT services.

Complex regulations on data flows increase corporate operating costs and risks and affect the development of global industry chains. After the *EU-U.S. Privacy Shield Framework* was invalidated in July 2020, Facebook came under strict scrutiny for its transmission of European user data back to the US. In October 2022, US President Joe Biden signed the *Executive Order on Enhancing Safeguards for United States Signals Intelligence Activities*, which substantially pushed forward the new framework for data transmission between the US and Europe and provided a more stable environment for digital companies to expand in the two regions. In addition, multinational technology companies such as Facebook, Google, Amazon, and Zoom have decided to set up data centers in Singapore, which may help Singapore become one of the world's most dynamic data center markets.[40]

The digital economy and digital industry chains are booming. Amid growing geopolitical differences, we believe that ensuring digital security, facilitating technological innovations and competition, and improving industry-chain efficiency are important issues in the digitalization of global industry chains.

First, we believe governments could value data as a factor of production, improve digital governance, ensure digital security, and effectively balance efficiency, equity, and security. Governments could strengthen regulations and advocate industry self-discipline to prevent companies from violating relevant laws and regulations such as the Cybersecurity Law, the Data Security Law, and the Personal Information Protection Law. Governments could also encourage companies to increase investment in scientific research and leverage technologies such as privacy computing to make data available but invisible during data flows. Companies should strengthen data analysis and improve the efficiency of data utilization without comprising original data or privacy protection.

From our point of view, while facilitating data localization, governments could closely monitor cross-border data flows in accordance with the guidelines for data export security assessments released in July 2022. In addition, governments may consider formulating a white list mechanism in due course and include eligible organizations or entities onto the list to improve the efficiency of cross-border data flows.

Second, we think China could strengthen corporate governance of digital platforms, improve regulatory frameworks, and facilitate law-based platform management. The competitive environment for the platform economy has improved in China due to strengthened governance and regulations in recent years.[41] While

[39] Article 33, 34 of Personal Data Protection Bill 2019 of India, https://dataprotectionindia.in/act/.

[40] https://finance.huanqiu.com/article/3zyBYpjhaLU [Chinese only].

[41] CICC Research, CICC Global Institute. *Building an Olive-shaped Society*. CITIC Press. 2022.

preventing platform companies from taking advantage of their scale to hinder innovation and form a winner-takes-all market, we should, in a scientific and appropriate manner, define the operating markets of platform companies, guard against excessive regulation and impediment of innovation, and encourage digital platforms to make effective use of network effects and existing scale to compete in the global markets with platform giants from the US and Europe. It is also important to improve the protection of consumers and small and micro enterprises, crack down on differentiated pricing based on consumer data, remove false information on the internet, maintain consumer trust in platforms and the digital economy, and make switching platforms straightforward for consumers.

Third, we believe governments could continue giving full play to economies of scale for large digital economies. China should continue to take full advantage of its domestic market, improve economies of scale in demand, and accumulate factors of production such as data. As of June 2021, the number of rural internet users in China had reached about 297 mn, but internet penetration rate in rural areas remained relatively low at 59.2%.[42] Therefore, the government could further strengthen the development of rural digital infrastructure and focus on investing in digital villages. In addition, governments could encourage and support Chinese digital platforms and industries to expand in overseas markets, and hence gradually grow to reach global scale.

We think governments can also play an active role in helping lower policy and other barriers for Chinese companies to go global, and create a level playing field for Chinese companies to compete in overseas markets. We suggest attaching greater importance to digital cooperation with countries in Southeast Asia and other neighboring countries, and fostering the emergence of an inclusive and expanding regional digital ecosystem with China at the core.

Fourth, we suggest leveraging the experience of the contactless economy amid COVID-19 conditions to improve the tradability of service sectors. It is essential to accelerate the removal of tangible physical barriers or invisible institutional barriers, build a two-way opening mechanism that boosts synergies between domestic and overseas markets and facilitate mutual development,[43] and foster high-standard opening-up of digital service trade. Amid limited progress in implementing the General Agreement on Trade in Services, we suggest paying attention to the **formulation of rules for regional cooperation in service trade**.

On the back of China's large market and industrial clusters, we believe governments can work on forming regional rules and mechanisms for digital service trade that are in the interests of various parties involved and on removing behind-the-border barriers to digital service trade, thus creating a favorable environment for China's service trade to go global.

[42] China Internet Network Information Center. The 50th Statistical Report on China's Internet Development. August 2020. [Chinese only].

[43] Hao, Shuang, et al. "Impact of digital service trade barriers and cross-border digital service inputs on economic growth." *Sustainability* 15.19 (2023): 14547.

Core technological innovation and advanced human resource are key engines for developing the digital economy. Governments could increase investment in basic science and long-term technologies that are characterized by high costs and risks so as to facilitate corporate innovations, in our view. In addition, industrial policies could be better targeted to avoid wasting resources. For example, industrial policies could lend more support to areas that are plagued by difficulties in mass production and slow client acquisition.

We also think that the government could encourage the corporate sector to increase R&D investment to stimulate innovation. The government could give adequate emphasis to the role of the capital market, optimize market-oriented resource allocation, and encourage the integration of high-tech companies. Given the technological constraints for China, we think the government could take full advantage of the country's economies of scale and demand and foster domestic and international cooperation in R&D.

Chapter 6
Global Industry Chains Amid Green Transformation: Opportunities and Challenges

Abstract Environmental movements in the 1960s marked the beginning of green transformation, and expedited the shaping of today's global industry chains. The international transfer of low-value added and high-pollution industries to developing countries created economic boosts as well as significant environmental pressure for these countries. What kind of changes would a new cycle of carbon neutrality-centered green transformation bring to the global industry chains? What challenges and opportunities would such changes bring to China?

We think the new round of green transformation may affect global industry chains in the following ways:

1) Rising energy consumption costs amid carbon neutrality. Over the short term, China's energy-intensive industries will benefit from the regulation of energy prices and low carbon costs (Carbon costs refer to the overall cost to emitters brought by carbon pricing and non-pricing policies. Carbon costs include abatement costs and the costs of remaining emissions), but we believe that the limited increase in energy consumption costs will be unfavorable for energy conservation and low-carbon upgrades. The traditional energy industry should see a short-term boost from energy price rallies but experience long-term pressure from a decline in demand. Meanwhile, the alternative energy industry will continue to thrive on stable expectations, while competition between countries may increasingly intensify.
2) International policies on preventing carbon leakage, such as the introduction of carbon tariffs, may narrow the carbon cost difference between countries. Such policies may add to restrictions on energy-intensive industries transferred to China from countries with stringent environmental regulations.
3) A meaningful green transformation cannot be achieved overnight. The global industry chains may continue to face rising climate costs and more frequent occurrences of extreme climate events over the long term. Industries with high exposure to climate risks, such as transport and logistics, agriculture, and energy,

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would be affected over the long term, and the impact would extend upstream and downstream via industry chains.

China has switched focus from "prioritizing economic growth over the environment" to "putting equal emphasis on the economy and sustainable development". Meanwhile, developed countries have started to protect their own green industries. This trend has led to fiercer international competition in global industry chains. Hence, we think that China's role in this new cycle of green transformation is to balance the development of green and traditional energy intensive industries as it adapts to or even leads the change in global industry chains.

Specifically, we believe China's goals of achieving peak carbon emissions and carbon neutrality should be in line with efforts to maintain energy security. While industrial competitiveness should be protected, energy price regulations should be gradually relaxed, and carbon restrictions tightened. Faced with an increasingly rigorous international environment, China could deepen international cooperation, and encourage the innovative development of green industries via sustainable financing and investment, in our view. Moreover, we believe China could fully leverage its economies of scale to strengthen the resilience and steadiness of industry chains when coping with climate risks. We think enhancing the competitiveness of emerging green industries will help improve industry chain efficiency as well as strengthen China's overall industrial security.

Keywords Green transformation · Internalization of environmental externalities · Costs of climate change

6.1 How Green Transformation Will Impact Global Industry Chains: Internalization of Environmental Costs

The switch in focus from minimizing environmental pollution locally to reducing carbon emissions worldwide has been expediting industrial transformation across the globe. The publication of Rachel Carson's *Silent Spring* in 1962 may have been one of the catalysts for the modern environmental movement in the US in the 1960s. Along with the United Nations Conference on the Human Environment in Stockholm in 1972, and the adoption of United Nations Framework Convention on Climate Change in 1992, the essence of green development has evolved and reshaped global industry chains.

Countries used to focus on the control of local pollutants such as chemical contaminants, air pollutants, sewage, and heavy metals when seeking sustainable development. In the 1960s, developed countries' adoption of stricter environmental policies and regulations forced the relocation of low-added-value and high-pollution

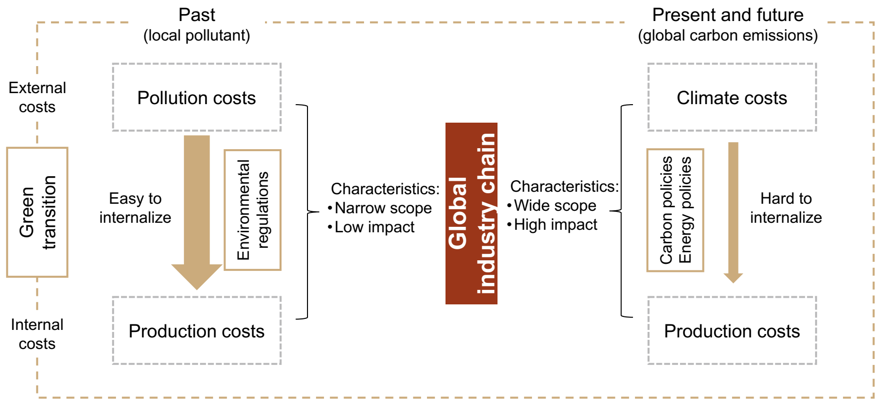

Fig. 6.1 Internalization of external environmental costs: Differences and similarities between controlling local pollutants and controlling global carbon emissions. *Source* CICC Global Institute

industries to developing countries.[1] As the goal of green development gradually shifted toward slowing climate change, countries began to propose carbon reduction or even net zero emissions, and introduced additional policies. At the macro level, green transformation should help restore efficiency loss caused by the negative externality of climate change, and the resolution of long-term climate risks produced by carbon-emitting activities should strengthen the security of industry chains.

Global industry chains seem to be undergoing a policy cycle similar to that of the control of local pollutants. As countries became more concerned about sustainable development, governments introduced environmental policies which internalized the negative externality of industrial production, resulting in environmental costs being transferred from the public to the polluters.[2] With environmental policies around the world reflecting varying levels of severity, producers in different countries faced varying internalized environmental costs, which in turn affected global industry chains. Whether the goal was to control localized pollution (as in the past) or global carbon emissions (as is currently the case and will continue to be so in the future), the fundamental premise that internalization of external costs will increase production cost remains unchanged.

However, we believe the control of carbon emissions will impact global industry chains more extensively and more deeply compared with the control of local pollutants (Fig. 6.1). The consequences of global climate change, such as frequent occurrences of extreme weather conditions and rising sea levels, may impact industry chains across countries. The ecological balance, once broken, is hard to be restored over the long term. It may cause more severe and extensive market failures, and result

[1] SHI Dan. "New Phase of Green Development and Global Industrialization: China's Progress and Comparison." *China Industrial Economics* 10(2018):14.

[2] Pigou, Arthur. *The economics of welfare*. Routledge, 2017. Coase, Ronald Harry. "The problem of social cost." *The journal of Law and Economics* 56.4 (2013): 837–877.

in higher external environmental costs. While local contaminants would only affect some activities in some regions during a certain period of time,[3] more parties are held responsible for global climate change, including both the direct polluters (mostly producers using fossil energy) and broad-sense polluters (energy consumers).

The internalization of external costs is achieved through policy instruments. Although the ultimate goal of reducing carbon emissions is mutually inclusive, not all policies at present are carbon policies directly aimed at achieving this goal. Other energy policies are also effective, such as control of both total energy consumption and energy consumption density, and renewable energy subsidies.[4] In the future, the energy consumption costs for companies will comprise energy prices (both fossil energy and renewable energy) and carbon pricing. Section 6.2 discusses the impact of energy consumption costs on global industry chains. Against the backdrop of worldwide carbon emission reductions, we believe that the different levels of severity of carbon policies adopted by various countries will lead to varying carbon costs, the impact of which on industry chains is discussed in Sect. 6.3. Since the internalization of external climate change costs cannot be achieved overnight, climate change costs are very likely to continue be borne over a long period of time. Section 6.4 analyzes its potential impact on global industry chains.

6.2 Rising Energy Consumption Costs: Gains and Losses in Energy Supply and Consumption Industries

6.2.1 Why Will Energy Consumption Costs Rise?

The green transformation trend is heralding increases in energy consumption costs. We discuss the cost of using fossil energy and renewable energy separately in this chapter. The cost of using fossil energy may increase due to two major reasons.

First, tightening of control over carbon emissions will drive up carbon costs. More and more countries have set net zero-emission targets in recent years.[5] While command-and-control policies such as a cap on total carbon emissions and carbon emission intensity created implicit carbon costs or shadow prices in the industry chains,[6] incentive policies such as carbon tax and carbon markets created explicit carbon costs, i.e., carbon pricing. The number of carbon pricing tools worldwide increased from nine in 2005 to 68 in 2022, and the coverage rate of carbon emissions rose from 5 to 23%.[7] Meanwhile, the carbon pricing policies have become

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[3] National Research Council, et al. *Hidden costs of energy: unpriced consequences of energy production and use*. National Academies Press, 2010.

[4] IEA. Combining Policy Instruments for Least-Cost Climate Mitigation Strategies. 2011.

[5] Net Zero Tracker. https://zerotracker.net/. August 19, 2022.

[6] Althammer, Wilhelm, and Erik Hille. "Measuring climate policy stringency: a shadow price approach." *International Tax and Public Finance* 23 (2016): 607–639.

[7] World Bank. State and Trends of Carbon Pricing. 2022.

increasingly stringent. The carbon quota prices in the EU continued to increase as EU countries adopted stricter climate goals and tightened carbon quotas. Moreover, carbon prices in other countries such as South Korea, New Zealand, and the US also increased, and may still have room for further upside, in our opinion.

Second, the decline in supply elasticity has led to more frequent and sharper increases in the prices of fossil fuels, raising energy consumption costs over the past two years. As policies such as carbon pricing and dual control over total energy consumption and energy consumption density were adopted, the market expected fossil energy demand to peak earlier and the stranded asset risks to increase. However, investments in fossil energy usually take a long period of time to recover. This has led to low levels of global capex on oil and gas exploitation. Moreover, we believe that the accelerated investments in clean energy may cause a crowding-out effect on fossil energy investments, and the geopolitical risks may rise further. Consequently, the elasticity of fossil energy supply may decline, which means energy producers will be more cautious about increasing output when energy prices go up.

An International Energy Agency (IEA) survey shows that oil and gas companies worldwide generally invested less in traditional oil and gas activities in 2022 compared with 2019 despite higher oil and gas prices.[8] In this case, supply cannot change simultaneously along with prices. Hence, any disruptions on the supply or demand side would not only drive fossil energy prices to surge, but also increase the medium-term price volatility.[9] For example, the Russia-Ukraine conflict disrupted natural gas supply, and led to a surge in global energy prices.

A major uncertainty over the supply of renewable energy is extreme weather. Against the backdrop of an accelerated shift in climate conditions and a higher proportion of renewable energy in total energy consumption in recent years, energy systems have been disrupted more frequently and more profoundly. In the UK where wind power is developing rapidly, the proportion of wind power in total electricity generation plummeted to 7% in September 2021[10] from 25% (the average level in 2020) due to a lack of wind in the North Sea, causing power supply shortages and a 100% increase in electricity prices.

The intermittency and volatility of renewable energy will continue to disrupt the stable operation of the power system. Power system costs will rise more rapidly as the penetration rate of renewable energy increases,[11] and efforts to reduce volatility will also drive up the cost of using renewable energy. Although advancements in renewable energy technology over the long term will drive down the cost of power generation and energy storage, it will require intensive R&D input, and the switch in industrial production models needed for green transformation would incur costs centering on electrification and intelligentization.

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[8] IEA. World Energy Investment. 2022.

[9] *Fluctuations and restorations amid Atypical Recovery* issued by CICC Global Institute (CGI) on September 24, 2022.

[10] https://www.fortunechina.com/shangye/c/2021-09/23/content_397903.htm

[11] OECD NEA. The Costs of Decarbonization: System Costs With High Shares of Nuclear and Renewables. 2019.

Overall, one of the intrinsic requirements for green transformation is to increase the fossil energy consumption cost. When it costs more to use fossil energy than to use renewable energy (i.e., when the green premium drops to below zero), the switch towards clean energy should accelerate, and fossil energy consumption should trend down, driving carbon emissions to decline. As the technology for renewable energy advances, the cost of using it will initially increase, then decrease.[12] We believe as the proportion of renewable energy in total energy consumption goes up, the overall energy consumption costs will also show an inverted U-shaped pattern, and the volatility of energy prices will eventually decline. However, for a considerable period of time in the future, the energy consumption costs will increase and remain volatile. What does the increase in energy consumption costs mean for global industry chains? We will discuss the impact on energy-intensive industries, the traditional energy industry, and new energy industry separately in this chapter.

6.2.2 Impact on Energy-Intensive Industries

Energy-intensive industries are the most directly affected by rising energy consumption costs due to high energy consumption density and carbon emission density. In China, over 10% of production costs are spent on energy use in industries, including nonmetallic minerals, metal smelting, chemicals, and transportation (Fig. 6.2). Assuming other factors remain unchanged, we estimate that every 10% increase in energy costs will drive up the total production cost of these industries by 1%.

In the previously published book *Guidebook to Carbon Neutrality in China*,[13] we estimated domestic green premium at 138% for building materials, 53% for chemicals, 15% for steelmaking, 11% for papermaking, 7% for petrochemicals, and 4% for non-ferrous metals in 2021. This also indicates the negative impact of rising energy consumption costs caused by internalization of external costs on energy-intensive industries. We believe that rising energy consumption costs will eventually lead to higher product prices and reduced output in energy-intensive industries. Moreover, increases in energy consumption costs during the early stages of the green transformation may result in economic stagnation.

We think efficient policies to control energy prices and low carbon costs may help reduce the actual energy consumption costs for domestic companies in energy-intensive industries in China. The price control policy hindered the pass-through of rising energy costs and delayed the impact of international energy price increases on domestic energy-intensive industries.[14] A computable general equilibrium (CGE)

[12] ZHANG Lei, et al. "Research on Power Consumption Cost Changes caused by Development of Renewable Energy during 14th FYP Period: Take Power Grids in Ningxia for Example." *Price: Theory & Practice* 4(2022):102-105.

[13] CICC Research, CICC Global Institute. *Guidebook to Carbon Neutrality in China.* Springer Nature Singapore. 2022.

[14] TANG Weiqi. *Dynamic General Equilibrium Simulation Research on the Impact of Macro Economy on Oil Prices amid Uncertainties.* People's Publishing House, 2013.

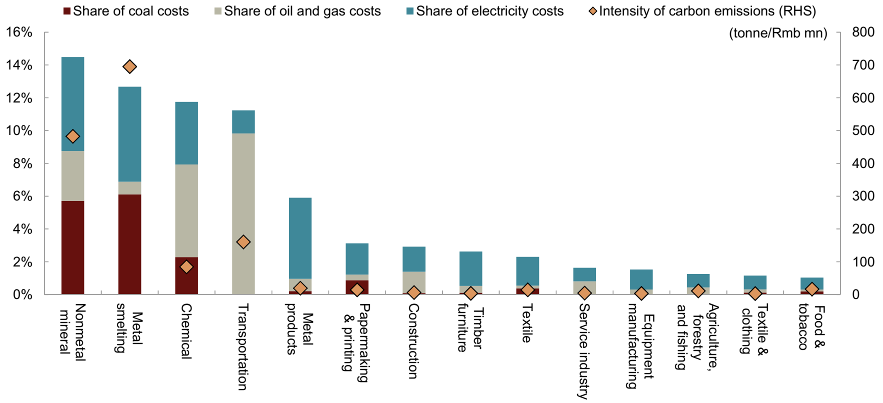

Fig. 6.2 Proportion of energy cost in total production cost and carbon emission density (2020). *Source* China national input–output (I-O) table [2020], CEADs, CICC Global Institute

model-based research study shows that the price control policy may reduce the impact of a 50% increase in international oil prices on the output and price rallies of domestic chemicals and transport industries from over 3% to less than 1%.[15] The relatively low energy prices in China helped enhance the international competitiveness of domestic energy-intensive industries.

While global energy prices surged after the Russia-Ukraine conflict, energy-intensive industries in China enjoyed low energy consumption costs owing to the price control policy. For example, unlike international coal prices, coal prices in China did not rise significantly, leading to a wide price gap between China and other countries. Moreover, energy prices increased much less in China than in Europe.[16] This created low-cost advantages for some energy-intensive industries in China, such as papermaking, aluminum, and chlor-alkali, and caused a surge in the exports of these products to Europe. Meanwhile, affected by the energy price increases in Europe, large numbers of companies in energy-intensive industries such as metallurgy cut or halted production, leading to sharp declines in output of aluminum and zinc.[17] The supply shortages in Europe also drove up China's exports of goods such as vehicles, machinery, and electronics.

The Russia-Ukraine conflict has sounded an alarm bell for energy and industrial security during the green transformation, highlighting the "impossible triangle" of energy security, economic growth, and clean energy. While Europe has made rapid progress in its green transformation, it relies heavily on the import of natural gas and other forms of renewable energy whose output is highly volatile. Meanwhile, other

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[15] JIA Zhijie, and LIN Boqiang. "State-owned Enterprises, Price Regulations and Economic Stability from the Perspective of China's Diesel Oil and Gasoline Market." *China Population, Resources and Environment* 32.7(2022):173–185.

[16] *Global Green Transformation Energy Supply Disruptions* issued by CGI on July 29, 2022.

[17] https://www.ft.com/content/0906df5d-1b92-4de1-95d6-3ae7b1055897

forms of energy such as coal and nuclear power were abandoned to some extent, increasing the fragility of Europe's energy supply.

When risk events such as the Russia-Ukraine conflict occur, Europe cannot respond quickly to guarantee energy supply, leading to the risk of energy shortage for industrial use and even the relocation of related factories to other regions. According to a 2022 survey by the Federation of German Industries (BDI), 58% of German companies faced serious pressure from rising energy prices, and 34% worried about bankruptcy.[18] Europe's largest automaker, Volkswagen, is considering moving its production base outside of Germany.[19] In the long run, increasing renewable energy supply will remain an effective way for European countries to reduce their dependence on energy imports and ensure stable energy supply for industrial use. However, as energy prices will increasingly fluctuate in the future, the stability of energy supply and price will also become increasingly important.

In terms of carbon costs, China's carbon reduction policies are not as severe as those in developed countries such as the US and those in Europe, and companies therefore are faced with less pressure from rising carbon costs. In theory, due to China's higher carbon emission intensity, its economy would be affected much more than those of such developed countries if it had to bear the same level of carbon costs.[20] However, in reality, the coverage of carbon pricing policies and carbon costs varies a great deal among different countries.

We calculate the explicit carbon cost by multiplying carbon price by the carbon emissions covered by carbon pricing. The explicit carbon cost accounts for 0.23% of GDP in China, lower than the 0.83% in the EU and 0.58% in South Korea[21] in 2021. Even taking the implicit carbon cost into consideration, we think the carbon costs in China will very likely be lower than in developed countries such as the US and those in Europe before China reaches carbon emission peak in 2030.[22]

Rising energy consumption costs have increased cost pressure on energy-intensive industries, but have simultaneously encouraged innovation in energy-saving and emissions reduction technologies, moving the development of industrial systems towards electrification and automation.[23] The theory of induced technological change suggests that changes in the relative prices of production factors themselves may

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[18] https://www.zdf.de/nachrichten/wirtschaft/bdi-insolvenzen-energiekosten-100.html

[19] https://www.sohu.com/a/587463954_119627

[20] LI Jifeng, et al. "Short-term Impacts of Carbon Market on Industrial Competitiveness and the Policy Options." *China Population, Resources and Environment* (2013).

[21] Source: Carbon Pricing Dashboard (World Bank).

[22] Aldy, Joseph E., William A. Pizer, and Keigo Akimoto. "Comparing emissions mitigation efforts across countries." *Climate Policy* 17.4 (2017): 501-515. ZHANG Xiliang, et al. "Research on China's Energy Policies and Energy Transition Path Towards the Goal of Carbon Neutrality." *Journal of Management World* 38.1(2022):35–51.

[23] Newell, Richard G., Adam B. Jaffe, and Robert N. Stavins. "The induced innovation hypothesis and energy-saving technological change." *Technological change and the environment*. Routledge, 2010. 97-126.

stimulate innovation, guiding technological change towards the more efficient use of relatively expensive production factors.[24]

The Porter hypothesis also suggests that strict environmental regulations may promote technological innovation, and even enhance industrial competitiveness.[25] For example, Japanese auto brands rapidly built market share in the US during the oil crisis in the early 1970s as their vehicles were better at conserving energy. It was during this time that the R&D around fuel cells also entered a fast track. The US expedited technological upgrades in the steelmaking industry through adoption of environmental regulation costs, which had at one point accounted for as high as 13–15% of the industry's total capex.[26] This policy contributed to the rapid boom in electric arc furnaces (EAF). The proportion of EAF in steel output and coal prices are positively correlated in Europe, and the former hit a high of 40% when the latter peaked in 2008.[27]

6.2.3 Impact on Traditional Energy Industry

The rising energy consumption costs will have both short- and long-term impacts on the traditional energy industry, in our opinion. Over the short term, we think the energy price hikes may benefit the traditional energy industry,[28] mainly considering relatively lower elasticity in energy demand and less stringent carbon regulations during the early stages of green transformation. Surges in oil and gas prices have led global oil and gas industry revenue to more than double compared with its five-year average,[29] and the market expects that US shale oil companies may generate free cash flow of US$180bn.[30] Over the long term, however, we expect traditional energy industry revenue to trend down. Energy consumers may gradually reduce their reliance on fossil-fuel energy as the cost to use such energy rises. In addition, we believe that higher carbon costs and unfavorable policies for the traditional energy industry will eventually weaken demand for fossil-fuel energy.

[24] Hicks, John. *The theory of wages*. Springer, 1963.

[25] Porter, Michael E., and Claas van der Linde. "Toward a new conception of the environment-competitiveness relationship." *Journal of economic perspectives* 9.4 (1995): 97-118. Jaffe and Plamer (1997) classified Porter Hypothesis into weak and strong versions, and they both agreed that environment regulations can boost innovation. However, only strong Porter Hypothesis believed the environmental policies can enhance companies' competitiveness.

[26] The Congress of US Congressional Budget Office. How Federal policies effect the steel industry. 1987.

[27] Source: Wind, Hithink RoyalFlush, iFinD.

[28] Thorbecke, Willem. "How oil prices affect East and Southeast Asian economies: Evidence from financial markets and implications for energy security." *Energy Policy* 128 (2019): 628–638.

[29] IEA. World Energy Investment. 2022.

[30] https://www.ftchinese.com/interactive/71270/en?exclusive

6.2.4 Impact on Alternative Energy Industry

We expect the alternative energy industry to benefit from the energy replacement effect in the coming period. As carbon regulations are tightened, the cost of consuming fossil-fuel energy will gradually exceed that of alternative energy, expediting the switch from fossil-fuel to alternative energy. Hence, we think alternative energy demand will remain strong over the long term. The rallies in fossil-fuel energy prices amid the Russia-Ukraine conflict are accelerating the global energy transformation and boosting growth in both volume and price for the alternative energy industry. The EU raised the target proportion of renewable energy sources in the overall energy mix from 40% to at least 42.5% for 2030.[31] Buoyant energy prices also increased demand for PV installations in Europe, boosting China's exports of PV products to Europe. In 2H22, China's total export value of PV products jumped 113% YoY to around US$25.9bn.[32] As strong PV demand will help sustain the growth momentum in major sectors along the PV industry chain, we expect domestic polysilicon producers to continue to expand capacity.[33] Moreover, other alternative-energy related industries such as energy storage and virtual power plants may also rapidly begin to thrive.

The increase in energy consumption costs would also help alternative energy companies strengthen profitability and reduce their reliance on government subsidies, which used to be the case for countries around the world as alternative energy costs more to use than fossil-fuel energy.[34] As the cost of generating power from alternative energy drops, we think the alternative energy market will gradually mature and enter a new stage of development after the subsidies are cut. We think the high energy prices should help strengthen the profitability of the alternative energy industry, and the switch from subsidies to carbon pricing will continue to boost industry development.[35]

The alternative energy industry is also attracting sustainable financing and investment. While the short-term energy price rallies may boost the traditional energy industry, the alternative energy industry is set to benefit more and offer more stable investment returns[36] during the energy transformation. Hence, financial instruments such as green finance and ESG investment tend to favor alternative energy. By end-2021, China had the largest amount of outstanding green loans around the world, and

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[31] https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets_en

[32] Ministry of Industry and Information Technology. China's PV industry in 1H22.

[33] *Forecast on Trend of Industrial Silicon Industry from the Perspective of Polysilicon Industry Development* issued by CICC Research on August 28, 2022.

[34] PENG Zhongwen, et al. "Impact of Government Subsidies on Performance of Renewable Energy Companies: Regulating Effect of Corporate Internal Governance." Journal of Central University of Finance & Economics7(2015):80.

[35] Aghion, Philippe, et al. "Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry." *Journal of Political Economy* 124.1 (2016): 1-51.

[36] IEA. Clean Energy Investing: Global Comparison of Investment Returns. 2021.

the second largest amount of outstanding green bonds.[37] Moreover, capital market-led ESG investment also brings numerous funds to the alternative energy industry.[38]

Aside from the growth opportunities, alternative energy companies in China may also face fiercer competition from overseas peers in terms of technological innovation. The alternative energy industry chain includes raw materials such as lithium, cobalt, and nickel, which rely more on natural resources, and manufacturing. The increase in demand would benefit the entire industry chain. However, it may give a stronger boost to the profits of raw material suppliers who enjoy a solid monopoly and higher bargaining power.[39]

Manufacturers, on the other hand, will require technological innovation to enhance their profits, in our opinion. China has limited battery metals. While domestic companies have developed many world-leading alternative energy technologies, there remains ample room for further innovation. For example, next-generation technologies such as solid-state battery and perovskite battery have become the latest development trend. We think technological competition among countries may intensify. China's alternative energy firms will need to resort to self-driven innovation to achieve high-quality growth.

6.3 Narrowing Difference in Carbon Costs: Changes in and Transformation of High-Carbon Industries

Countries around the globe are at different stages of decarbonization, and their carbon costs differ notably. It is difficult to quantify the difference in carbon costs caused by the adoption of different carbon policies, and we therefore use the carbon prices reflected in the carbon market or carbon tax policy. Among the countries currently implementing carbon pricing policies, South Korea and Japan both have over 70% of carbon emissions covered by the trading system, and the coverage rate is around 30–40% in the EU and China. The carbon prices are markedly higher in the EU and the UK compared to China, Japan, and South Korea. Most developing countries have yet to introduce a carbon pricing system, but many have already begun exploring this avenue. India's Energy Conservation (Amendment) Bill 2022 offers legal ground for the launch of a voluntary carbon market.[40] Vietnam issued its carbon market

[37] Research Bureau of People's Bank of China. Improving green finance system boosts high-quality green low-carbon development. 2022.

[38] BlackRock. Global Insurance Report. 2022.

[39] FitchRatings. Energy Transformation Boosts Global Long-Term Demand for Metals. 2022. IMF. Soaring Metal Prices May Delay Energy Transformation. 2021. S&P Global. The Future of Copper: Will the looming supply gap short-circuit the energy transformation? 2022.

[40] https://icapcarbonaction.com/en/news/india-establishes-framework-voluntary-carbon-market-and-outlines-pathway-towards-cap-and-trade

development plan in January 2022,[41] and Malaysia's Bursa Malaysia launched a voluntary market in December 2022.[42]

Theoretically, the "pollution shelter" hypothesis[43] suggests that high-pollution industries in countries with strict environmental regulations may be transferred to countries with less severe environmental regulations, causing an increase in greenhouse gas emissions (referred to as carbon leakage), with the difference in carbon costs possibly encouraging the industrial relocation.

In reality, countries worldwide had been seeking to reduce carbon emissions before the adoption of carbon neutrality policies, and the carbon cost difference already existed as far back as the late 1990s. Some sources attribute carbon leakage to the 1997 Kyoto Protocol: While countries that committed to carbon reduction saw carbon emissions decline, the carbon emissions implied in their exports from countries not bound by the agreement increased, resulting in the limitations of the Kyoto Protocol amid the transfer of high-carbon industries.[44] The carbon cost difference between regions within one country may also cause industrial transfer.[45] For example, high-carbon industries were transferred from eastern China to central and western China, where the carbon reduction policies are less severe. As a result, provinces in central and western China delivered above-average growth in carbon emissions.[46]

However, there are other sources that suggest that the transfer of high-pollution industries to developing countries was not simply an attempt to lessen their environmental costs. We think possible reasons for this could be that[47]: (1) The increased environmental costs resulting from the tightening of environmental regulations only accounts for a small proportion of the overall operating costs of companies; (2) the difference in environmental costs is not a major factor affecting the decisions being made by transnational corporations for foreign direct investment; factor endowments, infrastructure, and business environment all play important roles; and (3) pollution-intensive industries are mostly capital-intensive as well, and transferring these industries would require ground support for technological equipment which would involve

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[41] https://www.vietnambreakingnews.com/2022/01/vietnam-to-build-carbon-market/

[42] https://www.bursamalaysia.com/bm/about_bursa/media_centre/bursa-malaysia-launches-a-voluntary-carbon-market-exchange

[43] Copeland, Brian R., and M. Scott Taylor. "North-South trade and the environment." *International Trade and the Environment*. Routledge, 2017. 205–238.

[44] Aichele, Rahel, and Gabriel Felbermayr. "Kyoto and the carbon footprint of nations." *Journal of Environmental Economics and Management* 63.3 (2012): 336–354. Aichele, Rahel, and Gabriel Felbermayr. "Kyoto and carbon leakage: An empirical analysis of the carbon content of bilateral trade." *Review of Economics and Statistics* 97.1 (2015): 104–115.

[45] Cui, Jingbo, et al. "Carbon leakage within firm ownership networks: Evidence from China's regional carbon market pilots." (2022).

[46] TANG Weiqi, WU Libo, and QIAN Haoqi. "From Pollution Haven to Green Growth—Research on Regulatory System for Cross-region Transfer of Energy-Intensive Industries." *Economic Research Journal* 2016-6(2021):58-70.

[47] Copeland, Brian R., and M. Scott Taylor. "Trade, growth, and the environment." *Journal of Economic literature* 42.1 (2004): 7-71. ZHANG Youguo. "Cross-Region Trade from the Perspective of Carbon Emission: Pollution Haven and Factor Endowment." *China Industrial Economics* 2015.

additional expenses. This means the high-pollution industries would only be relocated when the carbon cost difference between countries is high enough to exceed the opportunity cost of international transfer.[48]

However, the aforementioned cost structure indicates that the carbon cost is lower than the energy cost, and the marginal impact of the carbon cost would be less when considering other costs. We therefore think the carbon cost is actually unlikely to cause industrial transfer. More importantly, the increase in external costs amid climate change would propel countries to adopt stricter policies to prevent carbon leakage, lowering the possibility of carbon price arbitrage. We summarize two major types of policies:

Border carbon adjustments policies are typically introduced for the prevention of carbon leakage. Many developed countries already take into consideration possible carbon leakage when designing their carbon reduction policy. The EU Emissions Trading System (EU ETS) grants free allocations of emission permits to leakage-prone industries,[49] and the EU Carbon Border Adjustment Mechanism (CBAM) continues to play its role after the free quotas are gradually canceled. CBAM charges carbon tariffs on exported goods for excess carbon emissions, which helps fill the carbon cost gap between EU and other regions and reduces the possibility of industrial transfer caused by the carbon cost difference.[50] Carbon tariffs would also reduce China's exports to Europe, especially machinery equipment, metal products, and petrochemicals.[51] In addition to the tightening of carbon regulations, many developed countries also introduce supportive policies to protect the competitiveness of their own industries. For instance, EU ETS revisions in 2022 proposed expanding innovative funds (to support the development of low-carbon technology, carbon capture, renewable energy, and energy storage in energy-intensive industries) and modernization funds (to support the modernization of the power sector and energy system in 10 lower-income EU member states).[52]

International organizations' restrictions on international economic activities. For example, airlines and shipping companies run their businesses across countries, and identifying which countries are relevant for their carbon emissions is complicated and becomes another major source of carbon leakage. The International Maritime Organization (IMO) and International Civil Aviation Organization (ICAO) have tightened control over these carbon emissions in recent years.[53] Such international policies have led countries around the globe to face greater pressure to reduce carbon

[48] Sato, Misato, and Antoine Dechezleprêtre. "Asymmetric industrial energy prices and international trade." *Energy Economics* 52 (2015): S130-S141.

[49] Felbermayr, Gabriel, Sonja Peterson, and IfW Kiel. "Economic assessment of carbon leakage and carbon border adjustment." (2020).

[50] Mörsdorf, George. "A simple fix for carbon leakage? Assessing the environmental effectiveness of the EU carbon border adjustment." *Energy Policy* 161 (2022): 112596.

[51] *Quantitative Analysis on the Impact of EU Carbon Border Adjustment Mechanism on China's Economy and Global Carbon Emission Reduction* issued by CGI on May 26, 2021.

[52] https://www.europarl.europa.eu/legislative-train/package-fit-for-55/file-revision-of-the-eu-emission-trading-system-(ets).

[53] https://www.imo.org/; https://www.icao.int/

emissions from the aviation and shipping industries. We believe that the resulting changes in transport costs will significantly impact global industry chains.

These international policies aimed at preventing carbon leakage may reduce the possibility of carbon price arbitrages in high-carbon industries. Looking back, we think global regulation of ozone layer depleting substances (ODS) went through a similar process. Like carbon emissions, ODS are also a worldwide negative externality as they damage the ozone layer and increase instances of diseases such as skin cancer. The Montreal Protocol on Substances that Deplete the Ozone Layer, signed in 1987, requires that countries gradually phase out ODS, with different timetables for developed and developing countries. However, developed countries' restrictions on imports of CFC refrigerators hindered the transfer of the CFC refrigerator industry to developing countries, and forced developing countries to start industrial upgrades earlier than planned.[54] Hence, we believe international policies designed to narrow the carbon cost difference will very likely reduce the possibility of international transfers of high-carbon industries, which may offset the carbon cost increase with energy conservation and low-carbon upgrades over the long term.

6.4 Climate Cost Increases: Challenges and Impact From Extreme Climate Events

Global warming is an issue caused by carbon emissions accumulated over centuries of industrialization. The global carbon cost cannot be internalized even over a long period of time. Moreover, historical data suggests that costs associated with climate change have continued to rise. According to data from NASA, the global temperature deviation from the historical average over 1951–1980 increased from −0.5° C in 1900s to around 0.8° C in 2021,[55] while the number of climate disasters rose from a few per year to 300–400 per year. Research by the Intergovernmental Panel on Climate Change (IPCC) indicates that global warming will significantly raise the frequency and intensity of extreme heat. The extreme high temperatures that occurred once a decade before industrialization may happen around 5.6 times every decade if the average temperature rises 2° C.[56]

Climate change may lead to increases in the Earth's surface and ocean temperatures as well as rising sea levels over the medium to long term, and more frequent and intense occurrences of extreme climate disasters over the short term. Such extreme

[54] ZHOU Xin, and CAO Fengzhong. "Implementation of Montreal Protocol and its Implications of China's Economy: Economic and Environmental Quantitative Analysis and Case Study of China's Refrigerator Sector." *Environmental Protection* 11(1999):4.

[55] https://data.giss.nasa.gov/gistemp/graphs_v4/

[56] Masson-Delmotte, Valérie, et al. "Climate change 2021: the physical science basis." *Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change* 2.1 (2021): 2391.

climate events may impact all industries and economic structures over the medium to long term, and disrupt industry chains over the short term.

Industries related to physical assets and natural resources are more vulnerable to extreme climate events, such as transport and logistics, agriculture, and energy. A global multi-sector CGE study[57] suggests that rising temperatures will negatively impact the agriculture, fisheries, forestry, energy exploitation, energy-intensive industries, and transportation in most countries. It would also affect other economic sectors via labor productivity and factor prices.

In addition to direct physical impact, climate risk events would also have an indirect impact on production factors. High temperatures also increase morbidity and mortality rates in many regions. According to the International Labor Organization, labor productivity would rapidly drop when wet bulb globe temperature (WBGT)[58] exceeds 24–26° C, and workers with moderate workloads would lose 50% of their working capacity when the temperature hits 33–34° C.[59] Tropical regions may see declines in labor supply and productivity as climate change intensifies, especially in sub-Saharan Africa, as well as some regions in South Asia and Southeast Asia.[60] Meanwhile, land, fixed assets, and infrastructure will more likely be affected by climate issues such as floods, hurricanes, and cold waves, which may damage or destroy physical assets such as real estate, and lead to insurance loss.[61]

The deep integration of global industry chains and the adoption of a lean production model allows the negative impact of climate risk events to extend along the industry chains, and to affect countries or regions where the downstream factories are located, creating a domino effect. For example, a flood in Thailand in 2011 was the most severe flood since 1970 led to suspension of production of over 10,000 factories in the auto, electronic and electric appliance manufacturing, and textile industries. As a result, Thailand's exports to Japan, Europe, and the US dipped 14%, 35%, and 21%, in November 2011. Due to the global production networks and low inventories under the lean production model, Japanese companies had to shut down the auto assembly lines in Thailand, leading to a 24.1% decline in Japan's auto parts exports in December 2011.[62] Some auto parts manufacturers suspended production

[57] Dellink, Rob, Elisa Lanzi, and Jean Chateau. "The sectoral and regional economic consequences of climate change to 2060." *Environmental and resource economics* 72 (2019): 309–363.

[58] Wet Bulb Globe Temperature (WBGT) is a fundamental criterion of the heat load of the environment to which people are exposed to.

[59] ILO. Working on a Warmer Planet: the Impact of Heat Stress on Labour Productivity and Decent Work. 2019.

[60] Dasgupta, Shouro, et al. "Effects of climate change on combined labour productivity and supply: an empirical, multi-model study." *The Lancet Planetary Health* 5.7 (2021): e455–e465.

[61] Breeden, Sarah. "Avoiding the storm: climate change and the financial system." *Speech given at Official Monetary & Financial Institutions Forum, London.* Vol. 15. 2019.

[62] Chongvilaivan, Aekapol. *Thailand's 2011 flooding: Its impact on direct exports and global supply chains.* No. 113. ARTNeT working paper series, 2012.

for as long as 174 days, and their net profit tumbled 50%.[63] A London insurance company paid a settlement of US$2.2bn for the event.[64]

The "bullwhip effect" in supply chain management normally involves random uncertainties and risks that can be rapidly resolved, and its impact on industry chain structure and output is limited.[65] However, climate risks are caused by complex meteorological factors which require rapid resource recombination or the search for alternative solutions to resume or sustain production and production networks amid a high level of uncertainties. The degree to which climate risk events impact global industry chains depends on multiple factors such as the characteristics of the industry chain. We think climate risks may lead to the short-term divergence of output in different regions, and the transfer or transformation of production over the long term.

6.5 Thoughts and Implications: China is Adapting and Leading

While global industry chains were reforming during the last cycle of green transformation, China was expediting industrialization and attracting international industrial transfers due to low-cost labor and resources. However, this created significant challenges, including pressure to protect the environment. In the beginning, the "pollute first and clean up later" model was necessary, and we think can be justified from the perspective of internal demand versus the external environment. Internally, rapid economic growth remained the national strategic priority since China's reform and opening-up in 1978 and until 2012. Environmental protection was sacrificed to boost economic growth during this period.[66] Externally, the environmental movements that emerged in the 1960s in developed countries propelled the international transfer of high-pollution and resource-intensive industries, creating opportunities for developing countries such as China.[67]

When analyzing China's role in global industry chains during the latest round of green transformation, we noticed changes in both internal demand and the external environment. The Chinese economy entered a phase of new normal after 2012, and

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[63] Haraguchi, Masahiko, and Upmanu Lall. "Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision making." *International Journal of Disaster Risk Reduction* 14 (2015): 256–272.

[64] Prudential regulation authority (Bank of England). The impact of climate change on the UK insurance sector. 2015.

[65] Smorodinskaya, Nataliya V., Daniel D. Katukov, and Viacheslav E. Malygin. "Global value chains in the age of uncertainty: advantages, vulnerabilities, and ways for enhancing resilience." *Baltic Region* 13.3 (2021): 78–107.

[66] WU Shunze, et al. "40 Years Evolution of the Relationship Between Environmental Protection and Economic Development in China." *Environmental Protection* 46.20(2018):7.

[67] LU Yang. "Environmental Issues in an Open Economy: A Survey." *Economic Research Journal* 2(2012):13.

economic growth became increasingly in sync with sustainable development. The phase-out of outdated capacity and industrial structure adjustments were all related to green upgrades. Externally, due to the worldwide negative externality of carbon emissions as described before, developed countries are morally going to prevent carbon leakage caused by industry transfer. Doing so also serves their own interest to create new economic growth drivers and enhance industrial competitiveness.[68] Meanwhile, some developing countries were early to recognize the importance of sustainable development. Hence, we believe China's major goal during the latest round of green transformation is not simply to protect high-carbon and energy-intensive industries but, more importantly, to balance the development of green and traditional industries in order to adapt to or even lead the change in global industry chains.

Over the short term, we think rising energy consumption costs amid green transformation will add cost pressure on manufacturing industries, and the instability of energy supply and the fluctuations of energy prices are detrimental to the security of the industry chain. Over the long term, however, we believe the higher energy consumption costs will stimulate energy conservation and advances in renewable energy technology, while encouraging countries that lack fossil-fuel energy resources to increase their supply of renewable energy and reduce reliance on energy imports. This should enhance both efficiency and security of the industry chains.

China provided a favorable environment for the development of domestic energy-intensive industries by effectively controlling energy prices and ensuring low carbon prices, but these industries, faced with less pressure to transition to sustainable energy sources, were less motivated to upgrade and innovate technologies. As a result, China's path towards reaching carbon emissions peak and carbon neutrality was hindered. Against a backdrop of more frequent increases in energy consumption costs and energy prices, China needs to strike a balance between achieving the goal of carbon emissions peak and carbon neutrality, and maintaining stable energy supply and prices. While industrial competitiveness should be properly protected, energy price regulations should be gradually eased and optimized, and carbon restrictions tightened. Furthermore, we think the clean low-carbon transformation should be advanced in fields such as industrial production and energy conservation. We also believe that carbon-reduction technologies should be developed and promoted to boost the greening of industrialization.

EU carbon tariffs aimed at preventing carbon leakage and international organizations' restrictions on carbon emissions for international airlines and shipping gradually weakened China's carbon cost advantage. International policies are becoming

[68] Meunier, Guy, Jean-Pierre Ponssard, and Philippe Quirion. "Carbon leakage and capacity-based allocations: Is the EU right?." *Journal of Environmental Economics and Management* 68.2 (2014): 262–279.

increasingly stringent. We think China could encourage its energy-intensive industries to adapt to the changes in international carbon-restriction standards[69] to reduce its negative impact on China's exports.

Strengthening international cooperation in coping with climate change and international coordination of green transformation may slow the backlash against globalization. Nevertheless, in light of China's advantages in alternative energy, developed countries have enhanced policy intervention, with an emphasis on localization and the security of the renewable energy industry chain. In our view, China could introduce favorable polices to boost innovation in green industries and encourage the development of sustainable financing. Industrial security is associated with competition between countries, and enhancing the competitiveness of emerging green industries may help improve industry chain efficiency and strengthen China's overall industrial security.

While the impact of climate change is negative overall, we think China may fully leverage its advantages to enhance its capability to adapt to these changes. China boasts a complete industry chain, which helps it to rapidly switch production capacity and resume production when faced with climate-related challenges. Awareness of adapting to climate change remains weak among all sectors of Chinese society, in our opinion, and the related management system needs to be improved.[70] Furthermore, coping with climate risks also requires more resilient and robust industry chains. At the macro level, China can fully leverage its economies of scale, and reduce regional risks via diversification of supply and demand. At the micro level, industries should assess climate risks before selecting new business sites to be able to shift from "just in time" (prioritizing costs by keeping inventory to a minimum, and being agglomerative and close to suppliers and customers) to "just in case" (diversifying to mitigate risks). Region-specific emergency plans for supply chain management should be made in advance to ensure the stability of the supply chain.

[69] National Standardization Administration. National Standard Plans and National Standard Foreign Language Plans for Carbon Emission Peak and Carbon Neutrality (2022).

[70] ZHENG Yan, et al. "From Climate Change Vulnerability to Adaptation Planning: A Perspective of Welfare Economics." *Economic Research Journal* 51.2(2016):14.

Chapter 7
Industrial Policy: Proactive and Effective

Abstract **Despite a lack of consensus on its effects, industrial policy has existed for a considerable period of time and is now back in the spotlight amid the changing global landscape.** In the 19th century, Germany used industrial policies to cope with international competition. After the Second World War, Japan also actively employed industrial policies. Vertically, the US and Japan both used industrial policies to promote industrialization when they were at the stage of catching up with other economies. After becoming leading economies, they shifted the focus of their industrial policies to promoting innovation. Horizontally, the US as a leading economy often used industrial policies to compete with latecomer economies if the competitiveness of the latter improved substantially. The world today is undergoing profound changes (e.g., green transition, the COVID-19 pandemic, competition between large countries, and the growing gap between the rich and poor) which not only affect market efficiency, but also affect security in a broad sense. Therefore, US and European governments have stepped up efforts to intervene, and industrial policy is back in the spotlight.

Profound changes call for a new mindset. The theoretical basis for industrial policies is shifting from neoclassical economics, which took center stage in recent decades, to political economy, and governments need to take proactive measures rather than occasionally intervene in the market when necessary. According to traditional views, the goal of industrial policy is mainly to solve problems related to market failures, including monopolies and externalities. However, in an era of profound changes, industrial policies should not only focus on efficiency, but also pay more attention to security. After analyzing policy targets, policy tools, income distribution modes, competition, and innovation from the perspective of the government's role, we believe the principles that industrial policies follow will change considerably. Industrial policies should shape and create new markets and be more comprehensive, focusing not only on manufacturing but also on service industries. Income distribution modes should also be improved as government investment increases. Industrial policies should not hurt competition while improving and strengthening

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industries and achieving economies of scale. Otherwise, they could be detrimental to innovation.

In an era of profound changes, China's industrial policy is multifaceted, but promoting innovation remains crucial. Industrial policies have played an important role in China's economic development, but they have also led to various problems. In the future, industrial policies should not only continue to improve efficiency, but also focus on social governance. For China's industrial policies, we think promoting innovation remains crucial, whether from the perspective of coping with profound changes or from the perspective of catching up with other countries. To promote innovation, we suggest increasing support for R&D. We believe government-guided funds are a good effort, but the market-oriented operations of such funds need to be improved. In an era of deglobalization, economies of scale are an advantage for China, but efforts should be made to avoid exacerbating monopolies, and to avoid improving security at the cost of lowering efficiency. We think expanding opening-up and attracting foreign investment are of far-reaching significance.

Keywords Industrial policy · Efficiency · Security · Social governance · Innovation

7.1 Industrial Policy Back in the Spotlight Amid Profound Changes in the World

The world's economic development has entered a new stage and is facing profound changes and grand challenges. Such changes and challenges include but are not limited to geopolitical conflicts, competition between large countries, trade policies that support domestic industries, the COVID-19 pandemic, supply chain disruptions, climate change, green transition, the gap between the rich and poor, etc. **These changes and challenges not only affect efficiency, but also affect security. "Security" here refers to security in a broad sense, including security related to social stability, energy security, and supply chain security.**

1) Competition between large countries is not only an economic issue but also a political one, and it is related to national security. Amid impacts from deglobalization, global cooperation is facing challenges, affecting supply, demand, and the operation of supply chains. Trade frictions and technology disputes are both manifestations of the imbalance in global governance against the backdrop of deglobalization.
2) The COVID-19 pandemic has had significant impacts, and governments proactively undertook emergency measures to protect the health of the public. From an economic perspective, public policies should not only ensure supply and demand, but also promote the transformation of the economic structure.

3) Maintaining the stability of supply chains implies that supply chain management should strike a balance between risks and rewards.[1] On the one hand, the private sector pursues efficiency, while the public sector attaches great importance to security. For society as a whole, the optimal combination of risks and rewards may be somewhere between the respective optimal combinations of the private and the government sectors. On the other hand, supply chains are highly complicated, and information asymmetry is a serious problem. Both governments and individuals may underestimate risks, and actual risks could be greater than the perceived risks. In such a context, if supply chains are hit, losses may be much larger than expected.
4) Climate change could increase the frequency and intensity of natural disasters, and a green transition is necessary. Carbon emissions have negative externalities. The rewards of economic activities generating carbon emissions belong to individuals, but the damage caused by carbon emissions is global. The green transition, however, will bring positive externalities as individuals may have to bear the cost of carbon emission reductions, but it will bring global benefits. As such, the private sector's investment in green technologies is insufficient. The green transition also raises questions about fairness. For example, regions that rely on fossil fuels for production may suffer more losses—should they be compensated for the losses incurred for the green transition? How should developing countries and developed countries play different roles in the process?
5) The growing gap between the rich and poor across the world affects not only economic growth but also social stability, and is both an efficiency issue and a security issue.

In response to these profound changes and grand challenges, the US and Europe have stepped up efforts to implement industrial policies. Against the backdrop of the COVID-19 pandemic and geopolitical changes, the US and EU have both proposed to enhance the resilience of local supply chains, and their common focus is mainly on five fundamental areas: Raw materials, active pharmaceutical ingredients, semiconductors, batteries, and renewable energy. In addition, the US also pays significant attention to the defense and transportation industries, while Europe pays close attention to cybersecurity and cloud computing. China has become a focus of attention and a keyword in the industrial policies of the US and Europe. This is not only because China's economic strength has improved and the country has become an important market in the world, but also due to increased economic and trade frictions between the US, Europe, and China.[2]

On August 9, 2022, US President Joe Biden signed the CHIPS and Science Act with a total investment US$280bn, with US$52bn earmarked for supporting chip and

[1] Baldwin, Richard, and Rebecca Freeman. "Risks and global supply chains: What we know and what we need to know." *Annual Review of Economics* 14 (2022): 153-180.

[2] Executive Order (E.O.) 14,017, America's Supply Chains, White House (2021); Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery, European Commission (2021); CICC Research.

semiconductor technologies with a focus on supporting the manufacturing of high-end chips. The major goals of the CHIPS and Science Act are to bring semiconductor manufacturing back to the US and to create new jobs in the country. With the signing of the bill, investments will be made to "poise US workers, communities, and businesses to win the race for the twenty-first century" according to President Biden.[3] During the Obama administration, the US introduced *the American Recovery and Reinvestment Act of 2009 (ARRA)* and *the Manufacturing Enhancement Act of 2010* to promote the development of domestic manufacturing industries in the US. During the Trump administration, the US implemented "America First" policies, introduced *the Strategy for American Leadership in Advanced Manufacturing*, and strived to bring manufacturing back to the US. After the outbreak of the COVID-19 pandemic, manufacturing jobs were brought back to the US at an accelerated pace. Statistics from the Reshoring Initiative in the US indicate that about 260,000 manufacturing jobs were brought back to the US in 2021, mainly from countries such as China, Mexico, India, and Japan.[4]

This means that despite a lack of consensus on its effects, industrial policies are back in the spotlight. Did Western countries eschew industrial policies in the past? Do arguments over industrial policies still make sense? How are industrial policies in an era of profound changes in the world different from those in the past? What are the lessons learned from China's industrial policies in the past, and what kind of industrial policies should be implemented in the future? What are the implications of industrial policies implemented by other economies? These are the questions we try to answer in this chapter.

7.2 Industrial Policies Have Been Adopted by Various Countries in the Past

7.2.1 Japan and the US Have Adopted Industrial Policies in the Past, but in Different Ways

In the past, industrial policies were mainly used to promote industrialization. Later, the focus of industrial policies expanded from the industrial sector to all sectors of the economy. In a narrow sense, industrial policy takes the form of government intervention in specific industries. Broadly speaking, industrial policy is "any type of intervention or government policy that attempts to improve the business environment or to alter the structure of economic activity toward sectors, technologies, or tasks that are expected to offer better prospects for economic growth or societal welfare

[3] https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/

[4] https://reshorenow.org/blog/reshoring-initiative-2021-data-report/

than would occur in the absence of such intervention".[5] The broad definition has been increasingly adopted in research on industrial policies, which in essence is about how to define the boundaries of government and market in the late twentieth century. We adopt the broad definition in this chapter.

In the 19th century, the German-born economist Friedrich List discussed the necessity of adopting trade protection policies to develop domestic industries in his work *The National System of Political Economy*. Meanwhile, Japan and the US have been continuously adopting industrial policies, albeit for different purposes, and in different ways and at different stages of development.

Industrial policies played a significant role in Japan's economic development after the Second World War, and the focus of the country's industrial policies shifted from a wartime economy to promoting innovation. (1) From 1945 to the 1960s, Japan's industrial policies still retained characteristics of a wartime economy. Direct regulation of private-sector economic activities through measures such as price controls, rationing, and prioritizing coal and steel production facilitated Japan's post-war economic recovery.

(2) From the 1960s to 1973, Japan's industrial policies adopted "hard measures" (e.g., tax incentives, subsidies, preferential financing, and trade protection) to support strategic industries. In 1960, Japan formulated the "income-doubling plan", focusing on developing heavy industries such as steel, petrochemicals, and machinery manufacturing.

(3) From 1973 to the 1990s, Japan's industrial policies adopted "soft measures" (e.g., administrative guidance, state-driven industry associations, and structural adjustments and assistance for supply and foreign exchange shocks) to support strategic industries. Industrial policies focused on areas of market failure, and took the form of providing public services, developing new industries, and adjusting declining industries.

(4) After the 1990s, the focus of Japan's industrial policies shifted to promoting innovation. In 1994, Japan's Ministry of International Trade and Industry released a report on industrial structure in the twenty-first century, identifying Japan's 14 major industries of the future, including information and telecommunications, energy, and high-tech manufacturing industries. In 2000, the Japanese government introduced a law on information technology, codifying the country's national strategy for information technology into law.

Since the US was founded, the country's industrial policies have undergone a transformation from industrial policies for industrialization to industrial policies for innovation, and from industrial policies for direct intervention to industrial policies for indirect intervention. The US adopted trade policies that support domestic industries prior to the Second World War. After its declaration of independence, the US was faced with an influx of industrial products from the UK and difficulties in the development of domestic industrial sectors. Alexander Hamilton, the first US Secretary of the Treasury, delivered a report on manufacturing industries to US Congress in 1791, stressing that the country was unable to develop an

[5] Warwick, Ken. "Beyond industrial policy: Emerging issues and new trends." (2013).

independent industrial system in the face of fierce competition from abroad. He proposed eleven basic principles for industrial policies, including tariff protection, import restrictions, direct government subsidies for target industries, tax exemptions for manufacturing inputs, and provision of public infrastructure. The average import tariff rate of the US rose from 8.5% in 1789 to 30% after the War of 1812. In 1930, the US announced the Smoot-Hawley Tariff Act, bringing the country's average import tariff rate to 65%.

The US government increasingly focused on technological innovation policies after the Second World War, in two stages. In the first stage, the US strived to promote breakthrough innovation in the context of the Cold War (1945–1980). The government increased public R&D investment and government procurement to improve national security and basic research. In 1958, the Defense Advanced Research Projects Agency (DARPA) was established to engage in advanced defense technology R&D. Technologies such as the internet, semiconductors, laser, and GPS technologies all originated from this government department.

In the second stage, the US strived to promote application innovation amid globalization (1980–2008). Faced with threats related to manufacturing and technology from the rise of Japan and Germany, it began to promote the commercialization of basic research. In 1992, the US launched the Small Business Technology Transfer (STTR) program to strengthen cooperation on innovation between small businesses and non-profit research institutes to improve the efficiency of commercialization of basic research. Mariana Mazzucato, a professor at University College London, believes that without the massive amount of public investment behind the computer and internet revolutions, Steve Jobs, co-founder of Apple, might have invented a new toy instead of cutting-edge revolutionary products like the iPad and iPhone which have transformed the way that people work and communicate. She also points out the success of Genzyme, an American biotechnology company which benefited from early research by public sector scientists.[6]

While focusing on technological innovation after the Second World War, the US continued to use industrial policies to compete with rivals. Japan's semiconductor industry grew rapidly in the 1970s and the 1980s, pushing US semiconductor companies such as Intel and AMD to the brink of bankruptcy. In 1985, the US launched a "Section 301" investigation into Japan's semiconductor products. In 1986, the two countries signed a semiconductor trade agreement, and Japan had to open up its domestic semiconductor market and ensure that foreign companies' products would gain at least a 20% market share in Japan within five years. Since then, the glory days of Japan's semiconductor industry have come to an end, and its market share in the global market has continued to decline.

By analyzing the history of industrial policies in major economies, we come to two solutions. First, the content and purpose of industrial policies vary in different stages of economic development. For example, the US and Japan both used industrial policies to promote industrialization when they were in the stage of catching up

[6] Mazzucato, Mariana. *The entrepreneurial state: Debunking public vs. Private Sector Myths.* Anthem Press, 2013.

with other economies, including policies that protected their infant industries and promoted exports. After becoming leading economies, the US and Japan gradually shifted the focus of their industrial policies to promoting innovation. Second, if the competitiveness of latecomer economies improves substantially, the US as a leading economy tends to use industrial policies to maintain its advantage and compete with latecomers.

7.2.2 Should the Government Adopt Industrial Policies? How Should the Government Use Industrial Policies?

Various countries have adopted industrial policies in the past, but criticism of industrial policies remains. Proponents of industrial policies argue that industrial policies address the problems of market failures. Generally speaking, market failures come from monopolies, externalities, information asymmetry, and shortage of public goods. Traditional industrial policies mainly address the problems of monopolies and externalities. For example, environmental pollution is a typical market failure phenomenon with externalities, and environmental protection policies are needed to restrict pollutant discharges.

Opponents of industrial policies argue that the existence of market failures does not justify government intervention in the market because government failures may also occur.[7] If a government failure is more serious than market failure, industrial policies could lead to greater losses.[8] Nobel laureate Gary Becker believes that "the best industrial policy is none at all".[9] There are two main sources of government failures: Information asymmetry and rent-seeking.[10] Information asymmetry means that the government often lacks information to select truly effective industries or companies. The problem of rent-seeking occurs when interest groups seek to obtain government support and protection through rent-seeking behavior. Politically connected businesses tend to have more resources for rent-seeking, which could be unfair to other businesses.

In order to correct market failures and avoid government failures, policymakers and scholars increasingly believe that industrial policy should play a role of indirect intervention and should reduce direct intervention. Direct intervention industrial policy tools include subsidies, credit, government procurement, and trade protection. Governments could use direct intervention industrial policy tools to provide resources to specific industries or enterprises in a targeted manner. The

[7] Datta-Chaudhuri, Mrinal. "Market failure and government failure." *Journal of Economic Perspectives* 4.3 (1990): 25–39.

[8] Rodrik, Dani. "Normalizing industrial policy." (2008). Naudé, Wim. *New challenges for industrial policy*. No. 2010/107. WIDER Working Paper, 2010.

[9] Becker, Gary. "The best industrial policy is none at all." *Business Week* 26 (1985).

[10] Krugman, Paul R., and Maurice Obstfeld. *International economics: Theory and policy*. Pearson Education, 2009.

advantage of direct intervention industrial policy tools is that they are quick to take effect and can rapidly boost employment and economic growth. The disadvantage of direct intervention industrial policy tools is that they could lead to government failure.

Governments could use indirect intervention industrial policy tools to establish rules, standards, and mechanisms that do not target specific industries or enterprises. For example, governments could either directly boost the production of goods in a specific industry through subsidies, or indirectly improve the competitiveness of the industry through anti-monopoly policies designed to increase production across the industry. The advantage of indirect intervention industrial policies is that they reduce the likelihood of government failure and problems such as information asymmetry and rent-seeking. The disadvantage of indirect intervention industrial policies is that they require long-term efforts and are unlikely to produce significant impacts in the short term.

A mainstream view is that direct intervention policies may be more effective if an economy is in the stage of catching up with other economies as the direction of economic development is clear in this stage and there is less information asymmetry between the government and market. However, indirect intervention policies may be more effective when an economy has passed the stage of catching up with other economies and is at the forefront of technology. In this stage, the government is no more aware of the direction of economic development than the market, and direct intervention is likely to be counterproductive. Based on a report released by the International Monetary Fund, truly effective industrial policies tend to be technology and innovation policies that intervene indirectly.[11] To develop technology and achieve innovation, the government should have its own goals. Industrial policies should not be limited to supporting industries with comparative advantages, but should also play an active role in creating markets and providing resources and taking responsibility for developing new industries. Industrial policies should focus on supporting industries with high complexity and be export-oriented rather than import-oriented. Industrial policies should also strive to maintain intense market competition.

7.3 Profound Changes Call for a New Mindset

7.3.1 New Mindset Amid Profound Changes in the World

Neoclassical economics is the theoretical basis for traditional industrial policies, and such industrial policies place emphasis on improving efficiency, but it is difficult for them to address the grand challenges that the global economy faces. Therefore, industrial policies need to be reimagined. Against the backdrop of profound changes in the world, new industrial policies introduced by the US and the EU indicate that

[11] Cherif, Reda, and Fuad Hasanov. *The return of the policy that shall not be named: Principles of industrial policy*. International Monetary Fund, 2019.

industrial policies no longer focus solely on efficiency, but also attach great importance to issues such as supply chain security, geopolitics, cybersecurity, and the gap between the rich and poor. For example, the "reindustrialization" of the US aims to both improve domestic fairness and reduce the possibility of transferring technologies to competitors, which has gone beyond the scope of neoclassical economics thinking.

Neoclassical economics is somewhat out of touch with reality, and the liberalization it has advocated over the past few decades has led to some of the grand challenges the global economy now faces. Therefore, we can no longer abide by the thinking of the past. For example, globalization has enabled multinational companies to establish a global presence, which has improved efficiency but weakened security and led to substantially elongated supply chains. Financial liberalization has also led to a growing gap between the rich and poor, threatening social stability. Neoclassical economics pays little attention to the issue of distribution. Pareto optimality holds a particularly strong political view of accepting the existing pattern of wealth distribution without addressing why a gap exists in the first place. However, from the perspective of political economy, market behavior must be subject to political and social ethics and values, and policies in reality must pay attention to issues of fairness and social stability. We think the new mindset amid profound changes in the world is that industrial policies should not only place emphasis on efficiency but also on security, and the theoretical basis for industrial policies is shifting from neoclassical economics in recent decades to political economy.

Some scholars have rethought industrial policies from the perspective of political economy. Nobel laureate Joseph Stiglitz believes that the current challenges stem from the failure of neoliberalism and the policy framework it supports, and that neoliberalism should be replaced by a new economic vision.[12] One example is mission-oriented industrial policy from a political economy perspective. Mariana Mazzucato believes that mission-oriented industrial policies in an era of profound changes should have more inspirational goals and focus on the public interest rather than just economic benefits.[13] In other words, we think industrial policies should address social problems in addition to economic problems. From the perspective of the government's role, industrial policies should not only passively solve the problems ignored by the market, but also take proactive measures and even play a role of leading the way.

Traditional methods for the evaluation of industrial policies are static and *ex ante* cost-benefit analysis, while the new mindset for industrial policies requires dynamic and systematic evaluation methods. In terms of attitude towards risk, failure is inevitable in the process of learning and thus policies should tolerate a certain degree of failure and improve risk tolerance. Overall, although mission-oriented industrial policies also have shortcomings (e.g., failure to consider issues such as

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[12] https://www.project-syndicate.org/commentary/russia-war-covid-global-shocks-reveal-bankruptcy-of-neoliberalism-by-joseph-e-stiglitz-2022-04

[13] Mazzucato, Mariana, and Rainer Kattel. "Mission-oriented industrial strategy." (2019).

government failure, inequality, and international cooperation), we believe the concept remains useful in thinking about industrial policies in an era of profound changes.

7.3.2 Five Basic Principles for Industrial Policies in an Era of Profound Changes

Based on the new mindset on industrial policies and drawing on existing research, we summarize some basic principles that industrial policies should follow in an era of profound changes in the world. These principles may not be comprehensive, but we think they indicate how industrial policies should change from different perspectives.[14]

1. The role of government: In the past few decades, the government mainly played the role of fixing market failure. In an era of profound changes in the world, the government not only needs to correct market failures, but also needs to take proactive measures to improve security and fairness. The government is becoming increasingly important as a market creator, i.e., shaping and creating new markets and guiding the direction of technological progress. Although the government has occasionally played the role of market creator in the past few decades, this role has become more important amid profound changes in the world. For example, addressing pollution is a case of correcting market failure, while the Apollo and Manhattan projects of the US government created new markets. In recent years, China, the EU, and the US have established carbon trading markets, and the US passed *the Inflation Reduction Act* in 2022 to promote energy transition and cope with climate change, which we think also reflects the government's role as a market creator.

2. Targets of policies: Industrial policies should focus on manufacturing industries as well as service industries, especially given the accelerated development of the digital economy. From the perspective of efficiency, industrial policies mainly promoted the development of manufacturing industries in the past. However, from the perspective of fairness, service industries now account for an increasingly large share of employment, and such industries cannot be ignored in order to narrow the gap between the rich and poor. We think industrial policies should pay attention to the development of service industries in the future. Dani Rodrik, an economics professor at Harvard University, proposed that the traditional focus of industrial policies on manufacturing industries needs to be broadened to service industries. The policies should place more emphasis on service industries, improve the productivity and labor income of workers in service industries, and create more jobs in service industries to address the current gap between the rich and poor.[15]

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[14] Aiginger, Karl, and Dani Rodrik. "Rebirth of industrial policy and an agenda for the twenty-first century." *Journal of industry, competition and trade* 20 (2020): 189–207. Mazzucato, Mariana. "The entrepreneurial state." *Soundings* 49.49 (2011): 131–142.

[15] https://www.brookings.edu/research/an-industrial-policy-for-good-jobs/

From the perspective of efficiency, the traditional view is that service industries are characterized by non-tradability, slow technological progress, and small spillover effect. In the era of the digital economy, the level of tradability of service industries has increased, and service industries are giving a stronger boost to the industrial sector and becoming an important source of productivity improvement amid improving tradability in service industries. Therefore, industrial policies should pay more attention to service industries. China released *Development Plan for Digital Economy during the 14th Five-Year Plan Period* in 2022, proposing that the proportion of key industries of digital economy in GDP should increase from 7.8% in 2020 to 10% in 2025. China's digital economy is growing rapidly, and we believe the size of a large country, as discussed in Chapter 5 *Digital innovations reshaping industry chains*, provides innate advantages for the development of the digital economy.

3. In the face of profound changes and grand challenges, industrial policies should be more comprehensive. (1) Traditional industrial policies often consider the development of one or two individual industries, and are often formulated by an individual government department and industry experts. In an era of profound changes in the world, industrial policies should expand beyond this scope and pay attention to multiple factors such as fair income distribution among industries, regional disparities, and competition between large countries. Therefore, industrial policies must be coordinated with various other policies. Taking the solar industry as an example, traditional industrial policies mainly consider how to promote the development of the solar industry alone. Against the backdrop of achieving the goal of carbon neutrality, the development of the solar industry could reduce carbon emissions and thus is related to all carbon-emitting industries.

(2) New industrial policies impose higher comprehensive requirements on the government's capabilities. In the face of major social challenges, market information provided by the private sector may be biased in terms of social value, and the government must be able to conduct independent and comprehensive information collection and analysis (e.g., individual companies are usually unable to collect supply chain information, and such information must be collected and shared by the government).

(3) Traditional industrial policies generally assume that technology is neutral (i.e., technological progress only improves efficiency without changing the proportions of income distribution among different groups of people) and that industrial policies should not proactively intervene in the path of technological development. In reality, technology is non-neutral and has different impacts on different groups of people, which could cause social problems. Therefore, industrial policies can proactively guide the development of technology. For example, technological development may lead to polarization in employment,[16] and technological development supported by subsidies for fossil energy may increase pollution. Therefore, industrial policies

[16] Acemoglu, Daron, and Pascual Restrepo. "The race between man and machine: Implications of technology for growth, factor shares, and employment." *American economic review* 108.6 (2018): 1488–1542.

need to comprehensively consider the efficiency and fairness issues of technological advances.

4. Income distribution modes: The government should place emphasis on developing rules to promote fair distribution of income. Industrial policy thinking in an era of profound changes implies that government investment may increase, and that this should be matched by suitable modes of income distribution. Otherwise, industrial policies may become unsustainable and widen the gap between the rich and poor. For example, the government should play an active role in technological innovation as innovation has positive externalities and may bring much uncertainty.

(1) Innovations and breakthroughs in fundamental technologies often produce substantial spillover effects, and it is difficult for innovators to enjoy the rewards of all the spillover effects. (2) Compared with risk, uncertainty in innovation is a factor that is more likely to result in inaction on the part of companies. Risk is characterized by probability distribution, and companies could take action based on expectations for risk. However, uncertainty has no characteristics of probability distribution, and companies tend to wait and see in the face of uncertainty as they have no experience to draw on.

Innovation of fundamental technologies is often accompanied by uncertainties. There is no probability distribution for which path of technologies may succeed and which may fail. The private sector cannot bear the cost of such large uncertainties. Therefore, the government needs to actively participate in the innovation of fundamental technologies. The government's heavy investment in innovation should be rewarded accordingly. Under the current market system, it is common for the risks and costs of government investment in innovation to be borne by the public but for the benefits to go to relatively few. Policies should change this situation to ensure the fairness and sustainability of innovation.

5. Industrial policies should not hurt competition while improving and strengthening industries and achieving economies of scale. Otherwise, they could be detrimental to innovation. Security and efficiency are negatively correlated from a static perspective or in the short term, but they are positively correlated from a dynamic perspective or in the long term. For example, emphasis on bringing back manufacturing to a country and strengthening its domestic manufacturing for supply chain security could reduce risks in the short term. However, in the long term, if the country's international competitiveness declines as a result, this would weaken its efficiency and security.

7.4 Promoting Innovation is Crucial Amid Multifaceted Industrial Policy in China

7.4.1 Historical Experience and Lessons for China's Industrial Policy

Since China introduced the reform and opening-up policy, the focus of the country's industrial policy shifted from promoting exports and the development of basic industries in the early stage to improving urbanization, then to promoting innovation and sustainable development (Fig. 7.1). In 1989, China's State Council released a policy document about the government's decisions on key points of industrial policies and it is the very first policy document named after industrial policies. In the policy document, the country laid out plans for the development of the country's industries at the time, focusing on developing basic industries such as agriculture, energy, transportation, and raw material industries.

In 1994, China released a policy document about the country's industrial policies for the 1990s, proposing that industrial policies should match the socialist market economy with Chinese characteristics and strengthen the role of the market in allocating resources. These industrial policies broke through the planned economy management model at that time, and gradually transformed planned management-oriented policy measures into policy tools such as investment approval, industry access, fiscal, taxation, and financial policy tools, which promoted the transformation of China's economy from a planned economy to a market economy.

After joining the World Trade Organization (WTO) in 2001, the focus of China's industrial policies shifted to the structural adjustment of industries. In 2005, the State Council introduced rules on promoting structural adjustment of the country's industries, proposing categories of industries to be encouraged, restricted, and eliminated. In 2012, the State Council released a policy document on plans for the development of strategic emerging industries during the 12th Five-Year Plan period to support the development of industries such as the information technology, biotech, and high-end equipment manufacturing industries.

Industrial policy has played an important role in China's economic development. In the past, China's industrial policies mainly focused on direct intervention and promoted the development of industries through subsidies, tax incentives, and government procurement. In recent years, the emergence of equity investment has reduced the direct intervention of industrial policies, resulting in a gradual shift to indirect intervention. We analyze China's industrial policy tools based on the country's industrial policies for the new energy vehicle, solar, and semiconductor industries.

1) Subsidies: For the solar industry, the State Council released a policy document in August 2013 on promoting the healthy development of the industry and introduced on-grid solar electricity price policies for different regions and standards on subsidies for distributed solar photovoltaic systems. China implemented a policy to

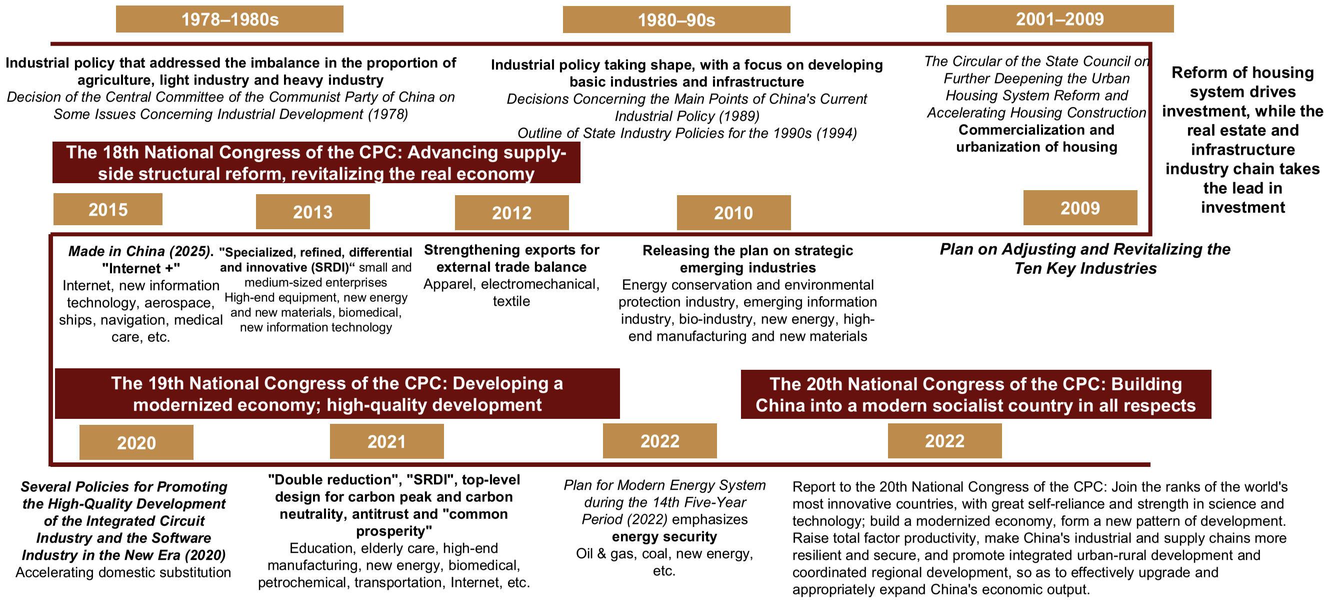

Fig. 7.1 Changes in China's industrial policies. *Source* Wind, Gov.cn, CICC Research

provide subsidies of Rmb0.42/kWh for the electricity generation of distributed solar photovoltaic systems.

2) Tax incentives: In 2012, China's Ministry of Finance and the country's State Taxation Administration released a policy document on the corporate income tax of companies in the software industry and the integrated circuit industry to further encourage the development of these two industries, and introduced various tax incentive policies (e.g., tax exemptions and halving of tax payments).

3) Government procurement: In 2013, China released a policy document on continuing to promote the use of new energy vehicles, stipulating that government agencies and public institutions should favor new energy vehicles when purchasing vehicles. For public transportation vehicles, government vehicles, logistics service vehicles, and sanitation vehicles, the proportion of new energy vehicles in newly-added vehicles or vehicles used to replace old ones should be at least 30%.[17]

4) Equity investment: In June 2014, the State Council released a policy document to promote the development of China's integrated circuit industry, making the development of the industry a national strategy. In September, a national integrated circuit industry investment fund was established in China, raising funds of more than Rmb100bn for equity investment in companies in the integrated circuit industry chain.

Overall, these policies have produced positive effects and boosted the development of the new energy vehicle industry, the solar industry, and the semiconductor industry. (1) The new energy vehicle industry has become a strong industry in China. Based on statistics from the China Association of Automobile Manufacturers, the sales volume of new energy vehicles in China increased by more than 430 times in the past decade from 8,159 units in 2011 to 3.52 mn units in 2021. (2) The solar industry in China has gradually overtaken that in Europe as the world's largest market for installed solar photovoltaic electricity-generation capacity. As of 2021, China's cumulative installed solar photovoltaic electricity-generation capacity was 306,403 MW and accounted for 36.3% of the global total, while that of the EU and the US accounted for 18.7% and 11.1% of the global total. (3) Thanks to policy support and tax incentives, significant progress has also been made in China's semiconductor industry. However, some problems have also emerged during the implementation of industrial policies. Taking the three aforementioned industries as examples, we can gain some experience and lessons from industrial policies for these industries:

1. Experience from success stories. (1) Industrial policies could expand economies of scale, reduce production costs, and enhance the competitiveness of industries through economies of scale. For example, the cost of solar electricity generation is high in its early stages of development and is uncompetitive compared to electricity generated by thermal power plants. Thanks to government subsidies, the cost of solar electricity generation has approached or even fallen below that of electricity generated by thermal power plants amid the expanding scale of solar electricity generation and cost reduction and efficiency improvement in various segments of the solar industry chain.

[17] http://www.gov.cn/zwgk/2013-09/17/content_2490108.htm [Chinese only].

(2) Industrial policies could be used to increase competition, which has been reflected in the development of the new energy vehicle industry. First, industrial policies could be used to break regional monopolies. In 2013, China released a policy document on continuing to encourage the use of new energy vehicles, stipulating that the number of new energy vehicle brands from outside a given region should account for at least 30% of new energy vehicle brands whose vehicles are encouraged to be used in the region, and no obstacles shall be created to restrict purchases of vehicles of brands from outside the region. Second, industrial policies could be used to attract foreign automakers and make competition in the new energy vehicle industry more market-oriented. Third, industrial policies could be used to encourage the adoption of the contract manufacturing business model for new energy vehicles and lower barriers to entry for new energy vehicle production. Under the contract manufacturing business model, new energy vehicle producers such as NIO, XPeng, and Li Auto have emerged, increasing competition in the market.

(3) Industrial policy subsidies should be withdrawn at the appropriate time. In May 2018, China released a policy document on solar electricity generation in 2018 calling for accelerating the reduction of subsidies for solar electricity generation to achieve market-driven growth as early as possible. Lessons from the solar industry show that the competitiveness of China's solar industry has been strengthened rather than weakened through market-oriented competition mechanisms after industrial policy subsidies were removed.

2. Lessons from inadequacies. (1) Overall, China's industrial policies have been successful and promoted the progress of industries. However, some problems (e.g., excessive investment) also emerged during the implementation of industrial policies. It should be noted that having problems do not mean that industrial policies have failed, but that room for improvement remains. (2) Some industrial policies have exacerbated environmental pollution and widened the gap between the rich and poor, and industrial policies under the new mindset should focus on solving these problems. While promoting the development of manufacturing industries, some industrial policies did not pay enough attention to the problem of environmental pollution, resulting in environmental damage. However, this problem has been addressed in recent years. In terms of the income gap, the simultaneous expansion of the real estate and financial service industries may widen the gap between the rich and poor.

To cope with these problems, we think two points merit attention. First, the implementation of industrial policies could be refined. The effect of industrial policy implementation is positively correlated with the government's capabilities in governance. Improving the government's ability to formulate, implement, and supervise policies could help to reduce failures. Second, industrial policies should focus on economic issues as well as social issues. Industrial policies in the past paid little attention to social issues (e.g., environmental pollution and the gap between the rich and poor), which should be one of the differences between industrial policies in the era of profound changes and traditional industrial policies, and is a topic of our discussion below.

7.4.2 Industrial Policy Should Play a Role in Multiple Aspects in an Era of Profound Changes

In an era of profound changes in the world, China's industrial policy should play its role in multiple aspects and not only promote economic development but also actively participate in social governance, including facilitating the green transition, narrowing the gap between the rich and poor, and improving supply chain security. China's industrial policies have stepped up efforts to cope with these issues, but still have much room for improvement.

1. Facilitating the green transition. (1) Raising carbon prices to internalize external costs; promoting technological innovation in energy conservation and emissions reduction. A large number of studies have found that a clearer carbon price signal could play a stronger role in driving innovations in low-carbon technologies and improving companies' willingness to develop and adopt low-carbon technologies. China's carbon market has been in operation since July 2021, and the cumulative number of companies participating in carbon trading has exceeded more than half of the total number of major carbon emitters in the country up to July 2022.[18]

(2) Accelerating innovation; fundamentally changing production methods. Developing new emissions reduction technologies and carbon capture technologies could reduce carbon emissions per unit of energy, and using clean energy could reduce energy consumption per unit of GDP. **To achieve the goal of carbon neutrality, efforts must also be made to improve social governance.** Efforts should be made to formulate corporate governance standards suitable for a low-carbon society, build an environmentally friendly financial system, improve carbon tax and carbon market systems, encourage low-carbon lifestyle habits, and advocate new consumption concepts. In the process of achieving the goal of carbon neutrality, attention must also be paid to the issue of fairness, and it is necessary to consider using fiscal measures to distribute the cost of carbon neutrality as fairly as possible, such as reducing the use of carbon taxes, increasing tax rebates, or using the collected carbon taxes to subsidize low-income earners.

2. Making use of digital technologies. In Chapter 5, we note that emerging technologies and new ways of organizing production and trade (e.g., digital platforms) are driving changes in factors of production, and service trade is likely to become a new growth driver. Industrial policies should focus not only on manufacturing but also on service industries. In the aforementioned chapter, we also note that attention should be paid to digital and data security, and building digital markets and a digital economy system.

3. Narrowing the gap between the rich and poor. The excessive expansion of the financial and real estate industries is an important reason behind the growing gap

[18] https://www.gov.cn/xinwen/2022-07/17/content_5701404.htm [Chinese only].

between the rich and poor, and the policy of "housing is for living in, not for speculation" has played a positive role in narrowing the gap in recent years. Meanwhile, the government has made other efforts to narrow the gap between the rich and poor:

(1) Introducing inclusive finance policies to encourage financial institutions to benefit the real economy. At end-July 2022, outstanding agriculture-related loans of domestic financial institutions stood at Rmb47.2trn, an increase of 1.6 times since 2017. As of end-July 2022, domestic financial institutions' inclusive loans to small and micro enterprises have maintained a growth rate of more than 20% for 39 consecutive months.

(2) Alleviating poverty through development of industries. Since 2017, China's new modern agricultural industrial park projects have covered 58 poverty-stricken counties, the country's advantageous and characteristic industrial cluster projects have covered 261 poverty-stricken counties, and its projects aiming to build towns with strong agricultural industries have covered 400 towns in 370 poverty-stricken counties.

However, we think it is necessary to further improve rules for financial markets and build a dual-pillar financial system. The efforts to build the so-called dual-pillar financial system are mainly efforts to build a financial system in which a guaranteed banking system and unguaranteed capital markets develop in parallel based on the premise that industries and finance should be separated and operate separately. In particular, the main mission of capital markets should be to offer equal opportunities and support innovation and development. The banking system needs to weaken its unreasonable competitive advantage from market-driven profits and government guarantees through a "non-profit-maximizing transformation", and vigorously promote the development of inclusive finance. It is also necessary to advance supply-side reforms for the real estate industry to narrow income disparities caused by housing. Efforts should be made to focus on the housing needs of new city dwellers and young people, and actively increase the supply of land for rental housing. Meanwhile, legislation should be accelerated to ensure that tenants and homebuyers have equal rights to basic public services, and to protect tenants in terms of rent increases and the setting of lease terms.

4. Improving economies of scale. In Chapter 3 *New advantages in economies of scale amid deglobalization*, we note that more attention needs to be paid to the role of economies of scale in promoting economic growth, and China has the potential to make the most of its advantage in economies of scale as a large country. On the demand side, industrial policies could narrow the gap between the rich and poor and improve equal access to public services. For industries, industrial policies could help to facilitate the circulation of goods and factors of production, build a unified domestic market, promote cooperation and development among industry chains, and eliminate monopolies. In terms of trade, strengthening international cooperation could play an important role in China's economic development and economies of scale.

5. Improving supply chain security. (1) Industrial policies could proactively improve information asymmetry between manufacturing and service industries. Traditional industrial policies mainly focus on individual industries, but industrial policies in an era of profound changes in the world should optimize the structure and coordination of production among various industries in the upstream and downstream segments of industry chains. In recent years, some local governments have begun to implement a "industry chain chief" system (appointing officials as chiefs of industry chains) and use industrial policies to facilitate connections between the upstream and downstream segments of supply chains. (2) Industrial policies could help to establish security measures for key agricultural products, which is of special significance to China and is part of supply chain security. China's grain reserves have long been above 70% of its annual consumption. The country's arable land area remained at 1.92bn mu (1,280bn sqm) in 2021 and its grain sown area was 1.76bn mu (1,173bn sqm). China's grain self-sufficiency rate has remained above 95%. (3) Industrial policies could be used to ensure China's energy security. Energy security issues have become increasingly prominent amid the green transition and geopolitical changes. At present, China still relies on fossil energy. In 2020, fossil energy sources accounted for 84.1% of the total energy consumption in China and non-fossil energy sources accounted for 15.9%. Meanwhile, China also relies heavily on imports of some energy sources, and the degree of the country's dependence on crude oil imports (net imports of crude oil divided by total domestic crude oil consumption) was higher than 70% in 2021. Therefore, industrial policies need to promote low-carbon transformation on the one hand and improve China's independent energy supply on the other.

7.4.3 Promoting Innovation Remains Crucial

In the past, China was mainly an economy catching up with other economies, but it is now beginning to take a leading position in some areas. The history of development of the US and Japan shows that the focus of industrial policies should be shifted from protecting infant industries and promoting exports in the stage of catching up with other economies to improving innovation in the stage of becoming leading economies. For China, innovation policies are particularly important. We think technological innovation could play an indispensable role in maintaining industry chain security and energy security, advancing the green transition, and narrowing the gap between the rich and poor. We believe efficiency improvement and economic development is the best way to fundamentally solve the current problems the world faces.

Since the 18th National Congress of the Communist Party of China, China has shifted the focus of industrial policies to technological innovation, including technological innovations in information technology, semiconductors, high-end equipment, alternative energy, and pharmaceuticals. In 2022, the 20th National Congress of the Communist Party of China proposed that China should achieve high-level technological independence and become a leading innovative country by 2035. Meanwhile, China should promote high-quality development, accelerate the establishment of a modern economic system, strive to improve total factor productivity, and improve the resilience and security of industry and supply chains. In *The Rise of China's*

Innovation Economy, we discussed how to improve China's innovation capabilities from three perspectives: Supply (R&D investment and human resources), demand (domestic and overseas demand), and ecosystem (regional and national innovation systems). Here, we discuss how to promote innovation from the perspective of industrial policies.

7.4.3.1 The Government Should Actively Participate in Innovation and Improve Income Distribution Mechanisms

Innovation has characteristics of positive externalities and considerable uncertainties, and thus requires government intervention to let industrial policy play its role. As innovation requires a large amount of government investment, the government should also enjoy the benefits of innovation. The system of income distribution in the market needs to be improved to increase fairness for the distribution of income from innovation. How should the government be rewarded for its investment in innovation? We think letting the government hold a stake in innovation projects could be a direction to consider. Government-guided funding is a good practice, but some problems remain at present.

7.4.3.2 R&D Policies Could Be More Effective in Promoting Innovation Than Direct Subsidies

Different industrial policies could play different roles in promoting innovation. Innovation activities are characterized by high risks and high returns, and it is difficult to predict which technology and which enterprise will succeed in innovation. Therefore, direct subsidies could face serious risks of information asymmetry, making it difficult to select potential "winners" in innovation. Compared with industrial policies that directly intervene (e.g., trade protection policies and subsidies for specific companies), R&D policies have a lower degree of direct intervention. Experience from the US over the past five decades shows that R&D policies appear to be more useful in promoting innovation, while trade protection policies and subsidies for specific companies result in mediocre outcomes.[19]

In areas where it has a leading position, China should strengthen supportive policies for R&D to promote innovation. From the perspective of economic development, the US and Japan gradually shifted the focus of their industrial policies from industrialization to innovation. China now has a complete industrial system, and the value added of the secondary sector as a percentage of GDP has fallen from 47% in 2010 to 39% in 2021. The US experience shows that government support and tax incentives for R&D have an advantage in supporting the innovation of small enterprises

[19] Hufbauer, Gary Clyde, and Euijin Jung. *Scoring 50 years of US industrial policy, 1970–2020*. Peterson Institute for International Economics, 2021. CICC Research.

and breakthrough innovation, while Japan has shown that bank credit has an advantage in supporting the innovation of large enterprises and incremental innovation. The advantage of government investment funds may lie somewhere between them. China needs both incremental innovation and breakthrough innovation. Therefore, we think the country should balance the allocation of resources for various policy tools and increase the proportion of tax incentives to support R&D. Data from the Center for Strategic and International Studies indicates that the proportion of R&D policies (including R&D tax incentives and government support for R&D) in industrial policies remains relatively low in China compared with that in the US, while the proportion of direct subsidies and credit incentives is relatively high in China.[20] We believe there is still inconsistency between the structure of spending for China's industrial policies and the country's efforts to innovate and transform. In the future, to promote innovation, we think China should increase the proportion of R&D policies in the country's industrial policies.

7.4.3.3 Efforts Should Be Made to Improve Market-Oriented Operation of Government-Guided Funds

Although industrial policy in the era of profound changes requires the government to play a greater role, this does not mean that innovation should be funded solely by the government. The government is only one contributor of funds for innovation, and the private sector should also play an important part.[21] Through cooperation between the government and enterprises, government-guided funds could help the government better identify truly efficient enterprises, which not only avoids the problem of information asymmetry, but also improves the efficiency of industrial policies. Compared with direct subsidies for enterprises, cooperation between the government and enterprises is a more effective form of industrial policy.[22] China's government-guided funds have grown rapidly in the past decade. By late 2021, China had established 1,988 government-guided funds with a target size of about Rmb12.45trn and about Rmb6.16trn of funds already in place.

However, some problems remain in the operation of government-guided funds in China, and there is room for further improvement. (1) The problem of objectives. Government-guided funds are sometimes involved in addressing the investment needs of local governments, and they may have to invest in some inefficient companies, which is not in line with the direction of technological innovation. (2) The problem of management. Some managers of government-guided funds are not selected on a market-oriented basis, and they may lack experience in the market-oriented operation of government-guided funds. (3) The problem of investment. Government-guided funds have relatively strict rules on regions where they invest, and they often impose restrictions to direct investments in local enterprises, which

[20] CSIS. Estimating Chinese Industrial Policy Spending in Comparative Perspective. 2022.

[21] https://bostonreview.net/forum_response/steering-finance/

[22] https://voxdev.org/topic/public-economics/where-are-we-economics-industrial-policies

could result in a tendency towards local economic preferences and lead to repeated competition among local enterprises. (4) The problem of performance evaluation. As it is difficult for government-guided funds to tolerate large losses, managers do not dare to invest funds in seed-stage or innovative start-up companies and entrepreneurs. Many government-guided funds invest in late-stage innovation projects (e.g., projects in the mature stage) or directly purchase wealth management products. Some funds are not sufficiently used, failing to meet the policy goals of promoting innovation and guiding structural upgrades of industries. Therefore, we think the efficiency of government-guided funds can be improved through methods of market-oriented operation, such as focusing the goal of government-guided funds on promoting innovation, selecting suitable fund managers on a market-oriented basis and reducing intervention as appropriate, relaxing restrictions on investments of government-guided funds and reducing local protectionism, and improving government-guided funds' tolerance of investment losses to enable investments in early-stage high-risk innovative companies.

7.4.3.4 Efforts Should Be Made to Avoid Improving Security at the Cost of Hurting Efficiency

Economies of scale should be an advantage of large countries in the context of deglobalization. Large-scale markets could help to spread the substantial R&D costs. Meanwhile, technology will continue to advance as the scale of production of products expands. However, we should be wary of exploiting economies of scale at the cost of exacerbating monopolies, thus impairing competition, hurting innovation, and lowering efficiency. Although monopolies could be conducive to innovation in the early stage, economies of scale would be substantially reduced over the long term in a monopolistic market rather than a competitive market. The behavior of enterprises is affected by the structure of market. A prolonged monopoly could weaken enterprises' motivation to pursue technological advances, and may even prompt them to maintain their monopolistic positions through rent-seeking. Balancing the relationship between competition and improving and strengthening industries is a challenge.

In the process of upgrading industries, China needs to rely on strong external competitors to motivate Chinese enterprises to some extent. Losing access to external markets or reducing imports of foreign products may weaken the competition faced by Chinese enterprises. Under the premise of opening-up, protective industrial policies are still necessary for some industries. However, historical experience shows that a certain degree of protection for industries could be conducive to the development of infant industries in their early stage, but foreign competition will become more important after such industries grow strong enough. China should not only support domestic companies to go global, but also strive to attract foreign companies to China. In the global value chain system, supporting domestic companies to go global could improve their innovation capabilities through competition. In terms of attracting foreign companies to China, we think it is necessary to expand market access to attract more foreign direct investment (FDI). According to AmCham China's China

Business Climate Survey Report (2022), 69% of surveyed companies reported unfair treatment with regard to market access. If China expands market access, 61% of surveyed companies would consider increasing investment in China, especially in the technology and consumer sectors. In a survey conducted in 2022, 22% of surveyed manufacturing companies plan to adopt a "China-plus-one" strategy and relocate some factories and suppliers to other Asian countries. Amid global geopolitical and industrial competition, China should adopt corresponding fiscal support measures such as subsidies, government purchases, and tax cuts to slow the transfer of FDI and maintain domestic competitiveness.

Chapter 8
Vertical and Horizontal Risks Along Industry Chains and a Dual-Pillar National System

Abstract International competition in trade has intensified since 2018, which we believe is determined by the objective, changing, and increasingly balanced strengths of countries. A shift from international competition in trade to deglobalization is being accelerated by the Russia-Ukraine conflict. The rollout of the US CHIPS and Science Act of 2022 has had further impacts on established patterns of cooperation, and international industry chains face security challenges caused by looming deglobalization. By examining horizontal and vertical risks, this chapter sheds light on the implications for the evolution of industry chains, financial reshaping, and institutions amid security challenges.

Vertical risks refer to the increased costs of transactions between all parts of industry chains amid deglobalization. The costs weigh on the existing pattern of serial production, and are essentially supply-side risks. Efforts to mitigate these risks require a centralization-based transformation of industrial organization. Specifically, vertical integration on the supply side of the chip industry and other high-tech industries and horizontal integration on the demand side of natural resource industries can help reduce vertical risks by utilizing the innovation capabilities of large companies and other organizations. Horizontal integration on the demand side of natural resource industries can also help improve China's bargaining power in international markets, thereby reducing vertical risks in natural resource industries.

Horizontal risks refer to the decentralization of China as one of the core nodes for global production capacity. Such risks are essentially demand-side risks and can be mitigated by diversification. Region-wise, we believe the moves to proactively switch the mature production capacity of textiles, home appliance, and other industries from China to Southeast Asia and surrounding countries, can increase regional cooperation. More importantly, we think competition among diversified small companies and "natural selection" can improve the capability of guiding innovation, and exports of the renewable energy industry and other industries in which China has advantages can build a new "China-surrounding countries" technology diffusion model. Domestic demand is insufficient in China, as shown by the country's

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low household consumption rate (household consumption as a percentage of GDP). In addition to eliminating consumption barriers in auto and other industries, greater importance should be attached to the efforts to propel fiscal and tax reforms so as to alleviate the effects of compulsory savings, build an “olive-shaped society” (CICC Global Institute, CICC Research. Building an Olive-Shaped Society (《迈向橄榄型社会》, Chinese version). CITIC Press Group. June 2022.) and tap the potential of diversification in consumption.

From the perspective of serving the real economy, we think the moves to propel restructuring of the financial sector should follow the principles of the separation of the financial business from industrial sectors and the separation of various financial sub-sectors from each other so as to support the co-existence of centralization and diversification of industry chains. Positive interactions between financial markets and the real economy are not spontaneous, and require policy intervention. This means that efforts should be made to build a national system that encompasses the strengths of governments and markets, and the strengths of financial markets and the real economy. A catching-up system for “big companies, big governments, and big banks” can help mitigate vertical risks, and a leading system for “small and medium-sized enterprises (SMEs), system construction, and capital markets” can help reduce horizontal risks. A dual-pillar national system, which is an important mechanism for efforts to cope with security challenges along industry chains, should be a necessary condition, rather than a sufficient condition. The two pillars play an essential role in dealing with security challenges, and efforts should be made to resolve boundaries between governments and markets, the metrics of monopoly and competition, and the relationships between large and small companies.

Keywords Vertical and horizontal risks · Centralization · Diversification · Dual-pillar national system

The CHIPS and Science Act of 2022, signed into law by US President Joe Biden in August 2022, includes a package of policies to support the development of the US semiconductor industry that requires recipients of financial assistance to sign an agreement prohibiting expansion of semiconductor manufacturing activities in China and other Countries of Particular Concern for a 10-year period. The US legislation exposes the division of labor along the international semiconductor industry chain to security challenges and reveals the intensified competition over industry chains. Such an intensified competition is determined by the changing strengths of countries, making the resulting security challenges along industry chains inevitable, and they may exist over the long term. With the Russia-Ukraine conflict accelerating the shift from competition to deglobalization, we think it is necessary to conduct a systematic study of managing the resulting security challenges and the potential evolution of industry chains.

The digital economy and green transition are of systematic importance to the evolution of global industry chains. The digital economy will likely reshape corporate boundaries. Since digital technologies reduce the cost of utilizing the market mechanism, companies that deploy them will likely continue to extend their boundaries as digital technologies may help firms reduce internal organizational costs and maintain their existing size.[1] The green transition imposes new restrictions on all industries as the cost of using environmental elements, supplied almost without limit at nearly zero cost under the extensive development model, will likely increase. For industries with different divisions of international labor, does industry chain security have the same implications? Are the risks the same across industries? With systematic factors such as the digital economy and green transition, do industry chains evolve in different directions? Should China utilize economies of scale, increase reliance on regional cooperation, or rely on industrial policies to cope with the evolution of industry chains?

We answer the above questions from three perspectives: Vertical changes along industry chains, cross-regional, horizontal movements of all parts in the production sector, and interactions between different parts along industry chains and between different countries along industry chains (also known as supply chain analyses). This chapter concentrates on the first two dimensions, Chapter 9 sheds light on supply chain analyses, several following chapters analyze different industries, and Chapter 18 focuses on the implications of investment.

8.1 The Origins of International Industry Chains: Technological Progress and Thawing of International Relations

The industrial organization of the semiconductor industry chain represents a typical Wintel model ("Wintelism"), characterized by modular outsourcing, division of labor, and collaboration. However, Microsoft and Intel did not popularize division of labor and collaboration, which had emerged earlier as part of the Toyota model ("Toyotism") in the 1970s. A mainstream view attributes the success of the Toyota model to the revolutionary concept of lean production. A central characteristic of lean production is that it reduces costs by operating with smaller inventories and reacts proactively to market demand for customization. If the concept of lean production brought about outsourcing, division of labor, and collaboration, why did the US, a country that underwent industrialization earlier than Japan, choose the vertically integrated Ford model in the 1920s? Why was a model of vertical disintegration, division of labor, and outsourcing not considered to improve production efficiency?

[1] PENG Wensheng, XIE Chao, and LI Jin. Corporate boundary, Say's Law, and Anti-platform Monopoly. February 2021.

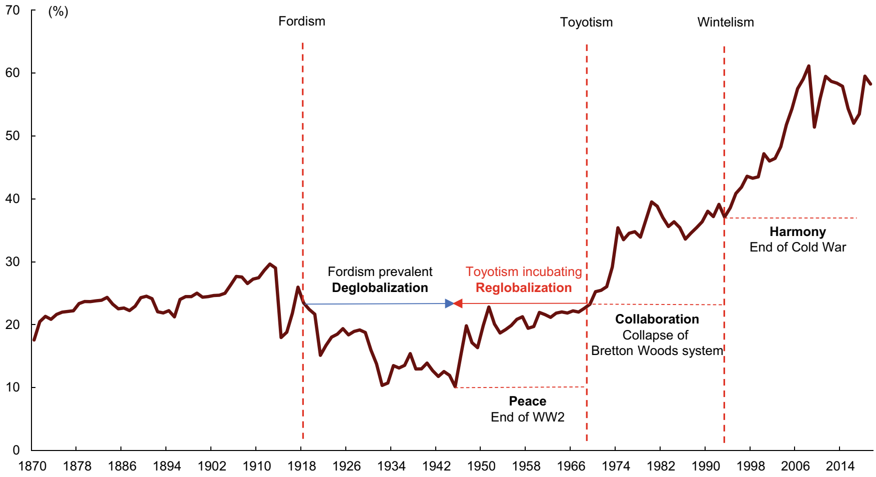

Fig. 8.1 Trade as a percentage of global GDP and forms of industrial organization. *Note* Data as of 2019. *Source* Our World in Data, CICC Global Institute

From a top-down perspective, we note that the prevalence of the Ford model in the 1920s and onwards coincided with deglobalization. As the isolation of national markets became increasingly clear, trade as a percentage of global GDP continued to decline, and the potential market sizes of companies continued to shrink. The Toyota model, prevalent in the 1970s, began to take shape in the early years of the post-war era at the same time as re-globalization. It might seem that re-globalization made the Toyota model possible, helping to turn the concept of lean production into reality (Fig. 8.1).

8.1.1 Improving Efficiency: The Implications of Vertical and Horizontal Industrial Organization Amid Globalization

Why don't companies outsource functions that are subject to diminishing returns to scale to specialized firms? We believe that because the size of the market for these functions might be too small to support specialized firms or industries.[2] An important implication of globalization for industry chains is that globalization can create a positive cycle which helps promote division of labor by increasing the size of the market, and division of labor, in turn, helps expand the size of the market.[3]

[2] Smith, Adam. *The wealth of nations [1776]*. Vol. 11937. na, 1937. Stigler, George J. "The Division of Labor is Limited by the Extent of the Market." *Journal of political economy* 59.3 (1951): 185–193.

[3] Youno, Allyn A. "Increasing returns and economic progress." *The economic journal* 38.152 (1928): 527–542.

Globalization may well explain why the idea of lean production could be put into practice under the Toyota model. The prevalence of the Toyota model was supported by post-war re-globalization, which brought about an expanding global market and promoted vertical division of labor along industry chains. For enterprises in the age of deglobalization, they need not only division of labor and collaboration, but also a large enough market scale.

From a horizontal perspective, we think globalization reflects the thawing of international relations. The world entered an unprecedented phase of relative harmony after the end of the Cold War in the 1990s. Global average tariffs declined year by year as international relations thawed. Today, China is the world's largest developing country, and the US is the world's largest developed country. Their cooperation is at the core of broader cooperation along international industry chains, giving rise to a G2 model that concentrates on the spread of technologies. According to the technological gap model, the difference in the levels of technologies between countries can help promote international division of labor and international trade.[4] The model suggests that leading companies with advanced technology typically outsource low value-added production to non-leading countries after developing new products. Non-leading countries collaborate internationally, and in the process of industrial chain division, gradually narrow the technological gap with leading countries through learning. Leading countries propel technological progress in lagging ones, and non-leading countries bring about increases in demand in leading ones, and the entire industrial chain cooperation process creates benefits for all participants. The technological gap promotes division of labor and collaboration between countries, and it also improves production efficiency.

8.1.2 Reducing Transaction Costs: Technological Progress Offers Possibilities in Reducing Transaction Costs; Thawing of International Relations Makes Possibilities a Reality

The traditional view emphasizes that the division of labor improves efficiency,[5] while ignoring that division of labor also incurs costs. Double marginalization was identified in studies of industrial organization conducted in the 1950s. This issue occurs when companies are arranged vertically into upstream and downstream collaborative production models. Upstream and downstream companies do not make the same profit, and they add markups along industry chains to maximize their profit, resulting in final product prices being higher than the vertical integration-based marginal

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[4] Posner, Michael V. "International trade and technical change." *Oxford economic papers* 13.3 (1961): 323–341.

[5] Smith, Adam. *The wealth of nations [1776]*. Vol. 11937. na, 1937.

costs.[6] Double marginalization shows that division of labor brings about increases in transaction costs, such as search, contract negotiation, supervision and control, and transportation. Factoring in transaction costs, we believe international division of labor occurs not only because it improves efficiency but also because the magnitude of the improvement in efficiency exceeds the magnitude of the increase in transaction costs.

Transaction costs inherent in international division of labor were reduced by two leading factors in the previous period of globalization: Technological progress and a thawing of international relations. Technological progress helped reduce the costs of transportation, telecommunications, and other transaction costs. Thawing of international relations reduced transaction costs among countries, and expanded the scope of the market economy. It is noteworthy that transportation and telecommunication costs declined more rapidly during the period of deglobalization before the end of the Second World War. With the end of the Second World War, the declines in transaction costs that were linked to technological progress moderated[7] before a new period of globalization started.

Globalization after 1945 can be divided into three phases, i.e., peace, cooperation, and harmony, according to trade as a percentage of global GDP (Fig. 8.1). First, the peace phase witnessed the beginning of re-globalization. Second, during the cooperation phase after the 1970s, globalization accelerated, to a large degree, benefitting from the collapse of the Bretton Woods system. The Bretton Woods system supported post-war economic recovery, promoting global integration in trade and other fields. The continuation of this system, which utilized fixed exchange rates and required restrictions on cross-border capital movements, also confined the development of transnational corporations and the depth of cooperation along international industry chains. The collapse of the Bretton Woods system was conducive to cross-border capital movement, and the resulting rapid development of transnational corporations gave rise to a second accelerated period of globalization.

Third, in the 1990s, an unprecedented post-Cold War harmony period emerged. Amid a thaw in international relations and accelerated globalization, countries worked cooperatively along industry chains. Rapid technological progress before 1945 brought about the possibility of globalization, but the world wars and other intense international conflicts offset the technological dividend and exposed the world to deglobalization. Overall, we believe that the technological progress brought about the possibility of reducing transaction costs in division of labor and collaboration and thawing of international relations transformed this possibility into the dividends of globalization.

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[6] Spengler, Joseph J. "Vertical integration and antitrust policy." *Journal of political economy* 58.4 (1950): 347–352. Bartelsman, Eric J., Ricardo J. Caballero, and Richard K. Lyons. "Customer-and supplier-driven externalities." *The American Economic Review* 84.4 (1994): 1075–1084.

[7] Jean-Yves, Huwart, and Verdier Loïc. *OECD insights economic globalisation origins and consequences: Origins and consequences.* OECD Publishing, 2013.

8.1.3 A Second Deglobalization: Intensified International Competition Pushes up Transaction Costs

International relations have thawed in the seven decades since the end of the Second World War. The evolution of international relations in peace, cooperation, and harmony, coupled with advances in telecommunications, information technology, and in other technologies, helped to notably reduce the transaction costs incurred by the horizontal international division of labor and the vertical disintegration of industry chains. These changes promoted globalization. However, it seems that globalization has come to a new inflection point. The pattern of international industry chains centered on G2 cooperation has faced challenges since the recent US-China trade frictions, which led to intensified international competition. The Russia-Ukraine conflict has accelerated the switch from competition to deglobalization. Efficiency improvement enabled by division of labor along international industry chains is at risk of being offset by higher transaction costs amid competition. International industry chains are faced with increasingly clear security challenges. We have analyzed implications of vertical disintegration and horizontal division of labor brought about by globalization. The implications of deglobalization for industrial organization can also be analyzed from vertical and horizontal perspectives (Fig. 8.2).

8.2 Vertical Risks: Utilizing "Centralization" to Mitigate Vertical Risks

Vertical risks are essentially supply-side risks. For example, the pattern of cooperation along high-tech industry chains is centered on the diffusion of technologies between China and the US, and is unlikely to continue. Vertical risks are notable in high-tech industries. In addition to vertical risks in high-tech industries, China is exposed to these risks in other industries. From the perspective of vertical serial production, China needs to obtain high-end equipment, intellectual property rights, key components, and other high-tech products from the US and other countries. It must also purchase raw materials from resource exporting countries. The methods for mitigating vertical risks in high-tech and natural resource industries are different. We believe vertical risks in high-tech industries should be resolved by vertical integration on the supply side, while horizontal integration on the demand side is the main method for mitigating vertical risks in natural resource industries.

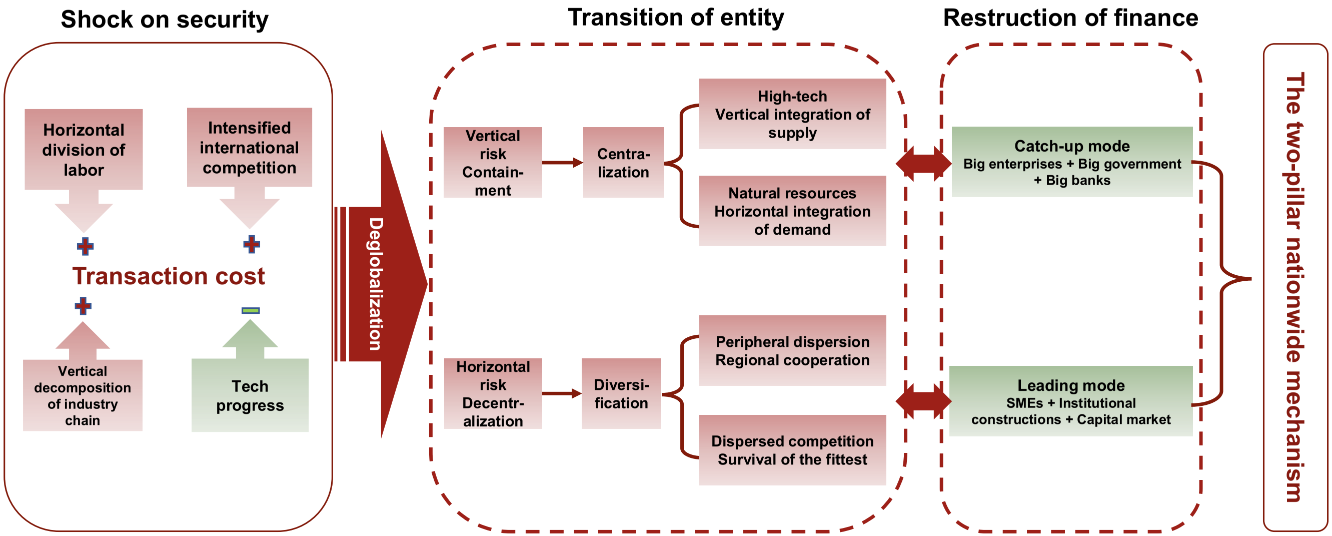

Fig. 8.2 Evolution of industry chains and a dual-pillar national system amid security challenges. *Source* CICC Global Institute

8.2.1 High-Tech Industries: Supply-Side Vertical Integration Accelerates Catch-Up Innovation[8]

At the micro level, vertical risks along industry chains include higher transportation costs, delays in component supply, and other supply chain risks. In Chapter 9, we argue that efforts should be made to improve supplier management and increase logistics, information flow, and capital flow-based interactions between upstream and downstream companies, thereby making supply chains more stable and resilient. The fundamental method for mitigating vertical risks in high-tech industries is to accelerate catch-up innovation. The move to return to vertical integration can help reduce vertical risks. The higher the costs of utilizing the market mechanism, the greater the willingness of companies to extend their boundaries. To extend these boundaries, companies may integrate vertically and reduce the steps in the division of labor, which can help them avoid increasing transaction costs amid intensified international competition. More importantly, vertical integration may utilize the advantages large companies have in catch-up innovation, mitigating vertical risks in high-tech industries. Compared to smaller companies, larger organizations typically own more intellectual property rights, invest more in R&D, boast greater human capital, and have more of the elements considered essential to innovation. Small companies mostly do not have sufficient collateral or stable cash flows, and their access to finance is limited. Large companies have comparative advantages in risk mitigation and financing. Their cash flows tend to be more stable, and they are more capable of bearing the burden of substantial R&D investment.

Vertical risks in the semiconductor industry, high-end equipment industries (such as high-end machine tools, robots, and aircraft industries), and other high-tech industries are essentially vertical risks related to industrial manufactured goods. The key to resolving these issues does not lie in continuously expanding the production capacity of manufactured goods, but lies in a range of production steps in upstream industries. It is noteworthy that Japan has clear advantages in the semiconductor material industry. Its global share of products in semiconductor manufacturing (mostly dynamic random access memory [DRAM] chips) notably exceeded that of the US in the 1980s. Japan began semiconductor manufacturing after the US. In the manufacture of mainstream chip-related goods and upstream raw material industries, Japan caught up with and surpassed the US by leveraging the Very Large Scale Integration (VLSI) plan launched in 1976. The plan had three main characteristics: Big government, big companies, and vertical integration. In terms of big government, the Japanese government directly organized related companies to form a group through which they cooperated closely. The former Ministry of International Trade and Industry was responsible for leading and offering technological support. Five big companies—Hitachi, Mitsubishi, Fujitsu, Toshiba, and Nippon Electric Company

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[8] Catch-up innovation refers to the introduction, absorption and research and development of new technologies through which a developing or less-developed country strives to catch up with developed countries. Simply put, catch-up innovation is innovation activity aimed at a technological catch-up.

(NEC)—were key enterprises in the plan. In terms of vertical integration, the five key enterprises vertically covered important parts along the industry chain. Thanks to this "big government and big companies-based" vertical integration, the VLSI plan helped Japan rapidly catch up with and surpass the US semiconductor industry.[9]

8.2.2 Natural Resource Industries: Demand-Side Horizontal Integration Helps Improve Bargaining Power

It is not just vertical integration that can help build big companies and industry groups. Horizontal integration can also centralize production, and help big companies leverage their advantages in innovation. German company IG Farbenindustrie Aktiengesellschaft (IG Farben) was one firm to utilize horizontal integration. Germany was a birthplace of the Second Industrial Revolution. While the country had coal mines, it lacked oil and other important natural resources. IG Farben played a substantial role in mitigating Germany's vertical risk in natural resources by developing coal-based synthetic fuels and rubber to resolve inadequate supplies of gasoline and rubber caused by limited oil reserves.[10] Innovative industrial production of urea, Nitrophoska, and other fertilizers helped notably improve agricultural productivity, and eased the impact of insufficient land resources on food supply.[11]

Horizontal integration laid the foundation for the firm's strong capability in innovation. In 1904, Bayer and BASF, two major chemical companies, along with the smaller firm AGFA, collaborated to establish an interest group in an example of horizontal integration. In 1916, Hoechst and four other chemical companies cooperated with the 1904 interest group to counter intense international competition in trade during WWI that was supported by the German government. In 1925, the eight members of the 1916 interest group merged into a single enterprise called IG Farben, putting the final touch to their horizontal integration by exchanging their corporate shares for those of the new enterprise.

Bayer, BASF, and Hoechst, the three largest firms among the eight IG Farben co-founders, were producing dyestuffs soon after their establishment at the end of the nineteenth century. These technologies were obtained from the UK, France, and other industrialized countries, and Germany soon caught up and surpassed both the UK and France in chemicals. In the UK and France, which had previously led the industry, organizations utilized horizontal integration strategies to compete with Germany.[12]

We think the history of IG Farben shows that horizontal integration helps companies share technology and other innovations, as well as raw materials. Using the

[9] FENG Jinfeng, and GUO Qihang. *Xin Lu* (Chinese title《芯路》). China Machine Press. 2020.

[10] Alfred D. Chandler, Jr. *Shaping the Industry Century* (Chinese version:《塑造工业时代》translated by LUO Zhongwei. Huaxia Publishing House. 2005).

[11] https://www.basf.com/ca/en/who-we-are/history/1925-1944.html

[12] Alfred D. Chandler, Jr. *Shaping the Industry Century* (Chinese version:《塑造工业时代》translated by Zhongwei, L. Huaxia Publishing House. 2005).

example of the firm’s second horizontal integration (1916–1925), we note that the eight members of the 1916 interest group operated independently, but emphasized the unified allocation of raw materials.[13] IG Farben centralized member companies’ demand for raw materials to the greatest possible degree after they merged into a single firm in 1925. This example shows that horizontal integration helps make centralization on the demand side of resources possible. Centralization enhances demand-side companies’ bargaining power against supply-side firms, helps improve the control that demand-side companies have over supply of resources, and mitigates vertical risks amid resource constraints. More importantly, we believe that, horizontal integration should be propelled by policy during a phase of intensified competition (factoring in the “resource curse[14]”).

Innovation and initiative play essential roles in the supply of chips, large aircraft, high-end machine tools, and other industrial manufactured goods. The allocation of property rights for industrial manufactured goods requiring advanced technologies is less subject to non-market forces, and it is influenced by people’s creativity and initiative. The geographical distribution of oil, iron ore, nickel, cobalt, and lithium is determined by nature. For a country, the use of geographic range which is dominated by the expansion of state power is a more effective means of obtaining more sufficient and reliable natural resources. Therefore, the more natural resources a country has, the more difficult it is for that country to have an advanced manufacturing industry. This country is more likely to be thrown into turmoil by intense competition between international forces. China accounts for a high proportion of the consumption of many natural resources that face vertical risks. However, China does not have advantages over sellers in the natural resource markets as Chinese buyers do not act in a collective manner in global resource markets, they negotiate separately with companies on the supply side, and they have yet to gain the positions that China should have in negotiations. We think intensified international competition means that countries are increasing intervention in their economies. Increased national intervention in natural resources which are mainly allocated by state power is inevitable. China should consider utilizing demand-side horizontal integration to improve its innovation capability and enhance its bargaining power so as to mitigate vertical risks in resources amid intensified competition.

[13] Ibid.

[14] Resource curse refers to the fact that some regions have a large amount of non-renewable natural resources, but instead fall into the dilemma of backward industrialization, difficult industrial transformation, and excessive dependence on a single economic structure.

8.2.3 Propelling Industrial Digitalization Transformation and Reducing Post-Centralization Internal Organizational Costs

Centralization, including supply-side vertical integration in high-tech industries and demand-side horizontal integration in natural resource industries, can push up internal organizational costs at companies and cause problems of diseconomies of scale and diseconomies of scope. Companies' operating efficiency may decline and their integration strategies may fail if these problems are serious. Judging from the experience of Tesla, we think industrial digitalization can help reduce post-centralization internal organizational costs. Modern automakers mostly utilize the Toyotism, which is characterized by division of labor and collaboration along industry chains, while it seems that Tesla is shifting back to vertical integration represented by the Ford model. Tesla does not seem to have notable problems with diseconomies of scale, diseconomies of scope, or higher internal organizational costs. First, Tesla utilizes advanced production technologies to reduce its internal organizational costs. For example, integrated pressure casting substantially reduces the number of components involved in manufacturing and shortens the process compared with traditional autobody pressing and welding techniques. The firm requires fewer employees and manufacturing facilities, thereby notably reducing its internal organizational costs and gaining efficiencies in vertical integration. Tesla is not a conventional automaker; it is a digitalized company engaged in car-making activities. The firm has a decided advantage in industrial digitalization. For example, Tesla has built a software and hardware integrated operating model[15] and construct a digitalized service ecosystem.[16] Data elements, unlike oil and other physical resources, are virtual resources. Digitalized companies with substantial data are likely to conduct cross-sector business operations and gain economies of scope.[17] Industrial digitalization can also help companies reduce internal organizational costs and create economies of scale. Efforts should be made to propel industrial digitalization in tandem with vertical and horizontal integration so as to reduce post-centralization internal organizational costs and improve the capabilities of mitigating vertical risks.

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[15] The firm has rolled out independently-developed chips and automated driving technologies.

[16] The company has launched its in-house version operating system and acquired Twitter.

[17] XIE Chao, and LI Gen. Public resource theory-based Analysis of Platform Data. June 2022.

8.3 Horizontal Risks: Utilizing Diversification to Mitigate Decentralization Risks

In an environment of security challenges, there are vertical and horizontal risks for industry chains. As shown by changes in global trade flows of finished products over 2000–2019, China overtook Japan to become one of the three largest global trade centers for finished products (Fig. 8.3). The other two centers were the US and Germany. The tripartite pattern has evolved into a pattern in which China has accounted for a larger share of global trade flows of finished products since the beginning of the COVID-19 pandemic. Influenced by deglobalization, the US and Europe have recently rolled out policies to reduce their reliance on the center of production capacity in China, giving rise to decentralization related horizontal risks. Centralized big companies and groups can naturally help non-leading countries catch up. However, non-leading countries that intend to take leading positions need to keep improving their capabilities in new sectors and industries. The US has a strong capability of guiding innovation, which we believe is mostly attributable to diversification and competition among small companies, and to the rapid growth of these companies. **Factoring in security challenges, we believe centralization is required only in industries that have vertical risks, and diversification is needed to mitigate decentralization risks. Diversification can help improve the capabilities of guiding innovation and make possible the sustained cooperation between China and surrounding countries.**

8.3.1 Regional Cooperation: Relocating Production to Southeast Asia and Surrounding Countries; Increasing Regional Cooperation Along Industry Chains

The first question China needs to answer is: Does it needs to maintain all industry chains in its efforts to mitigate decentralization risks? For industry chains that are in severe oversupply, can moves to keep all production capacity within the country ensure the security of industry chains? All countries make a trade-off between security and efficiency due to their resource limitations. Securing industry chains does not mean a country should pursue large production capacity in all industries. Instead, countries should make themselves irreplaceable along international industry chains.[18] It seems that keeping all production capacity along mature industry chains

[18] CICC Global Institute, CICC Research. Chapter 1: Technological innovation enhances security and efficiency of industrial value chain. The Rise of China's Innovation Economy (《创新: 不灭的火炬》, Chinese version). CITIC Press Group. 2021.

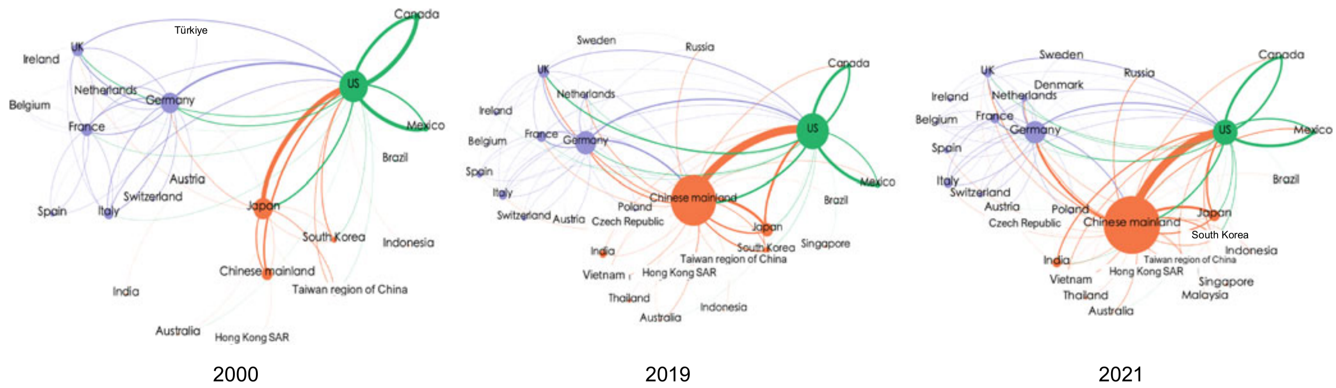

Fig. 8.3 Global trade flows of finished products. *Note* Finished products refer to final merchandise exports absorbed by direct importing countries. According to the analysis framework of global value chains, a country's total exports can be broken down into exports of finished products, and exports of intermediate products. The curves represent the export of goods from the upstream node to the downstream node in a clockwise direction. Regarding node colors, purple represents Europe, orange represents Asia and Australia, and green represents the Americas. The color of the curve is the same as the color of the exporting country. The size of the node represents the total export value of the economy, and the thickness of the curve represents the size of the bilateral trade volume. The chart shows bilateral trade of more than US$5bn (measured in 2000 constant USD). *Source* Gross Trade Accounting: Official Trade Statistics and Measurement of Global Value Chains (WANG Zhi, WEI Shangjin, and ZHU Kunfu. *Gross trade accounting method: Official trade statistics and measurement of the global value chain.* Social Science in China Press, 2015.), ADB MRIO database, CICC Global Institute

that are in severe oversupply in China is unnecessary. Diverting such production capacity to other countries and regions can help mitigate horizontal risks.

Which regions will benefit China most, if China diverts production capacity to these regions? First, as shown in Fig. 8.3, the economic and trade ties between China and the US notably exceed such ties between other economies. The ties between most Asian countries, such as Southeast Asian countries, and China were closer than their ties with the US. The curves that linked China to other countries grew thicker in 2021 compared with their levels before the COVID-19 pandemic in 2019. In addition, the ties between China and Southeast Asia also grew notably. Second, horizontal risks in an environment of deglobalization are that the linkages between the three trading centers, especially the linkage between China and US, will likely weaken. Weakened ties between the three trading centers mean that other economies within each cluster will be of greater importance to regional centers. Direct ties between the three centers are likely to weaken, and they are likely to build indirect ties by increasing their cooperation with other economies within each cluster. In a period of deglobalization, the ties between the three regional centers and other nodes will likely play a greater role compensating for the weakening ties between the three regional centers. This shows that moves to increase regional cooperation are important for mitigating horizonal risks. We think that Southeast Asia may be the top pick for China as it takes the initiative to guide the diversification of mature industrial chains.

Which industry chains should be diverted? From the perspective of horizonal risk, we think China should first consider diverting industries that are in severe oversupply. Most of these industries are also targets for decentralization in a period of deglobalization. China's factor endowments are switching from abundant labor and scarce capital to abundant capital and scarce labor. Even if there were no horizontal risks in decentralization, the rising labor costs linked to the fading demographic dividend would no longer support China's large-scale production capacity. China may divert capital to countries that have large labor forces, combining its capital and the human resources[19] of other countries. Members of the Association of Southeast Asian Nations (ASEAN), many of which are enjoying a demographic dividend, may take the lead in receiving mature industries that are notably subject to rising labor costs. Diverting industry chains to these countries, and increasing cooperation between China and ASEAN along industry chains, can help China utilize regionalization to mitigate horizontal risks. These moves conform to changes in the pattern of China's endowment factors, and will likely enhance China's interests.

[19] XIE Chao, and WU Yunjie. Possible Paths Across the New Demographic Trap. May 2022.

8.3.2 Supply: Diversification, Competition, and Natural Selection; Utilizing Small Companies to Improve the Capabilities That Guide Innovation

In the effort to mitigate horizontal risks, China should consider if it is possible to divert production capacity to nearby countries. Whether a potential target country is willing to accept China's production capacity is an important limiting factor. As a result, China needs to maintain its appeal to non-leading countries by transferring advanced technologies in an effort to increase regional cooperation and smooth the migration of industry chains, in our view. The technology diffusion-based pattern of industry chain cooperation between China and surrounding countries is more sustainable than the G2 technology diffusion model. We believe that to maintain long-term cooperation between China and smaller economies, China must have a long-term and sustainable advantage in innovation, which can be attractive enough to these countries in terms of technology transfer. Given the technological gap-based product cycle theory,[20] we think China should continue to develop new products, technologies, and industries in order to build a sustainable "China-surrounding countries" technology diffusion model. This would help China maintain a leading position in technology, lay the foundation for sustained regional cooperation along industry chains, and mitigate horizontal risks in a more effective way. Efforts to build the capabilities that guide innovation require decentralized small companies rather than centralized large companies. In terms of R&D spending and human resources, larger companies enjoy competitive advantages over smaller ones in innovation capabilities. However, we believe innovation requires more than technological strength: It also needs a high propensity and strong capabilities to change organizational structures, i.e., adapting to the change of external environment and enhancing the competitiveness of enterprises.

From a corporate perspective, leading innovation in many cases refers to new products that are differentiated from current mainstream products,[21] which naturally embeds the ability to disrupt the products made by large companies. As a company becomes larger, it faces greater obstacles when embracing leading innovation, since its interests and those of its partners and shareholders tend to be tied deeply to its products. In contrast, smaller companies face lower internal organizational costs when pushing leading innovation. We believe they are more willing to rely on leading innovation to challenge the dominant positions of large companies. Positive externalities from innovation indicate that smaller companies can turn their propensity for leading innovation into revolutionary products even if their technologies are less

[20] Vernon, Raymond. "International investment and international trade in the product cycle." International economic policies and their theoretical foundations. *Academic Press*, 1992. 415–435.

[21] For companies, moves to create new products, new industries, and new sectors are known as qualitative innovation (aggressive innovation or radical innovation). Qualitative innovation is referred to as leading innovation in this report, as this report sheds light on innovation from the perspective of competition between countries. Similarly, catch-up innovation amid competition between countries are equivalent to progressive innovation and other quantitative innovation at the corporate level.

advanced, in our opinion.[22] Smaller companies are more likely to promote leading innovation, and they play an indispensable role in mitigating horizontal risks. In its efforts to avoid large companies' overreliance on mature technological paths, China can give full play to SMEs' spirit of innovation when it moves mature production capacity to other countries. The market mechanism, which is characterized by decentralized competition and survival of the fittest, should be allowed to choose the future technological route so as to enhance the possibility of China's continued leading development in advantageous industries.

8.3.3 Demand: From Overreliance on Centralized Investment to Increasing Diversified Consumption Potential

The implication of diversification for leading innovation is also reflected in the fact that diversified demand is more likely to propel leading innovation. Companies may utilize differentiated innovation to meet the needs of different consumers. A company is likely to gain higher returns via innovation if it identifies differentiated market demand earlier than other companies, and responds to the demand through R&D and production.[23] The success of a supply-side differentiation strategy, to a large degree, is determined by demand-side diversity. As demand becomes more diversified and more differentiated, it is likely to prompt companies to conduct more radical leading innovation, in our view.

Diversified demand can help unleash the consumption potential of large countries, mitigating decentralization-related horizontal risks. Judging from US history since 1980, we think the rapid outward migration of industry chains will likely result in the problem of "middle class collapse",[24] a state of economic stagnation in which the incomes of well-educated middle class groups stagnates. One way to resolve this issue is to consider the job market's ability to withstand the migration of industry chains. However, structural fine-tuning of industries and the progress of productive forces should be taken into account. The key to resolving this issue lies in the efforts to expand domestic demand and support reemployment of displaced workers. Such efforts require support from policies to stimulate domestic demand. Regarding demand, domestic and foreign demand, investment demand, and consumer demand can all boost GDP. However, different types of demand have different implications for security of industry chains amid deglobalization. (1) Domestic and foreign demand:

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[22] CICC Global Institute, CICC Research. Chapter 16: Financing innovation—Capital markets not the only player. Innovation: Keep the Torch Burning (《创新: 不灭的火炬》, Chinese version). CITIC Press Group. 2021.

[23] Lancaster, Kelvin. "Change and innovation in the technology of consumption." The *American Economic Review* 56.1/2 (1966): 14-23.

[24] CICC Global Institute, CICC Research. Chapter 16: A Two-pillar Financial System and a Good Society. Building an Olive-Shaped Society (《迈向橄榄型社会》, Chinese version). CITIC Press Group. June 2022.

Other countries are unlikely to influence China's decisions on the geographical locations of its industry chains no matter how high the tariffs or non-tariff barriers that these countries impose on China's products are if China's production capacity is utilized to meet China's domestic demand. The fundamental reason why some of China's industry chains face horizontal risks is that other countries implement tariff policies on the back of their substantial domestic demand. (2) Investment demand and consumer demand: Production is the means, while consumption is the purpose.[25] As a country's household consumption rate rises, it becomes more appealing to manufacturers when they decide the geographical distribution of their manufacturing facilities. Higher rates of household consumption are essential to countries amid deglobalization since only household spending power can offset the downward pressure on aggregate demand. In China, foreign demand and investment demand currently account for a high proportion of total demand, while household consumption is relatively low.

More importantly, China's household consumption rate is lower than the level implied by its demographic dividend.[26] Possible reasons include the lack of consumption scenarios and limited spending power. The lack of consumption scenarios refers to a situation in which people have spending power but consumer demand is not fully realized. For example, the potential demand for automobiles, which is an essential part of household consumption in developed countries, has yet to be fully unleashed in China. We think efforts could be made to alleviate restrictions on consumption scenarios such as restrictions on purchasing cars. Insufficient purchasing power is a more important reason behind the low rate of household consumption in China. Attention should be paid to the effects of compulsory savings, which is caused by a system that divides taxes between the central and local governments, competition between local governments, and land-based financials.[27] Theoretically, moves to increase investment and demand can boost economic growth. However, we think the implications of such moves are different from the perspective of the competition among local governments. Government expenditure that is earmarked for local households to directly boost consumer demand in a region will likely cause the spillover of household demand to other regions, while government expenditure utilized to boost local investment in a region generally helps increase fixed assets within the region. Competition among local governments means the achievements of a local government are reflected not only in its performance but also in comparison with other regions. Local governments under this model are more willing to stimulate investment in a centralized way, and are less likely to utilize consumer demand, which is more fragmented.

Moreover, in this system, which divides taxes between the central and local governments, local governments are reliant on land parcels to obtain the proceeds earmarked for centralized investment, which is in fact a form of land-based financial activities, in our view. Under the land-based financial model, local governments'

[25] Marx, Karl. *Capital, Volume I: A critique of political economy. Vol. 1.* Courier Corporation, 2011.

[26] http://www.50forum.org.cn/home/article/detail/id/10472.html [Chinese only].

[27] Land-based financials refer to the moves to obtain proceeds from the sale of land use rights.

sources of independent income are correlated with the price of land parcels, and the upside potential of land prices are determined by housing prices.[28] The land-based financials model is a reason behind the high housing price to income ratio in China, and it also gives rise to the effects of the compulsory savings that dampen consumer demand.

Overall, the moves to offer production and goods for consumption to the fast-growing working population required substantial investment when China enjoyed a demographic dividend. Centralized investment under the competition model played an important role in China's economic growth. However, as the demographic dividend wanes, the model and the land-based financials in the system that divides taxes between the central and local governments are hindering the consumption potential in China via compulsory savings. To mitigate horizontal risks amid deglobalization, efforts should be made to reduce the overreliance on the centralized investment-based economic growth model. China could utilize fiscal and tax reforms to reduce compulsory savings, and build an olive-shaped society to unleash the seemingly fragmented but substantial consumption potential of households.

8.4 A Dual-Pillar Financial System: Implications of Financial Reshaping Amid Vertical and Horizontal Risks

From the perspective of serving the real economy, we think the financial industry should propel restructuring of financial organizations that support the evolution of industry chains amid security challenges. By examining the relationship between financials and innovation, this section sheds light on the implications of the evolution of industry chains for the organizational restructuring in the financial industry.

8.4.1 We Think Banks Are Better Suited for Supporting Catch-Up Innovation Led by Big Companies

The vertically integrated VLSI plan in Japan and horizontally integrated IG Farben in Germany utilized the innovation capabilities of large groups to mitigate vertical risks. Japan in the 1970s and Germany in the early twentieth century were economies dominated by banking systems. Commercial banks were an important source of funds

[28] CICC Global Institute, CICC Research. Chapter 16: A Two-pillar Financial System and a Good Society. Building an Olive-Shaped Society (《迈向橄榄型社会》, Chinese version). CITIC Press Group. June 2022.

for the VLSI plan.[29] However, a mainstream view holds that banks are ineffective in propelling innovation and may be detrimental to innovation, a view that contradicts the experience of Japan and Germany. This mainstream view considers only financial structure, and neglects the structure of innovation. In fact, innovation can be divided into “catch-up” innovation, “leading” innovation, and innovation by large firms, smaller ones, mature companies or startups. The formation of financial structures in Japan and Germany was directly linked with the “catching-up” strategies of countries lagging in international competition. German unification took place at the end of the nineteenth century. There was a strong desire for the country to catch up with the UK, France, and other leading countries. German banks mobilized their financial forces to provide a full range of financial services for companies. The government was tolerant towards mixed business operations and integration of financial business and industrial sectors. These moves facilitated the formation of the universal banking system in Germany. Similarly, Japan during the Second World War needed to utilize banks, which were more subject to government control than other financial institutions, to centralize financial forces across the country and build a banking system in its efforts to support its enormous war machine. In our view, the risk appetite of commercial banks is not closely related to corporate innovation, but is mainly driven by their liabilities and operating models. Commercial banks do not effectively support innovation among smaller firms with little collateral or startups with unstable cash flows, in our view. However, they seldom refuse to support innovation among larger companies with ample collateral or startups with stable cash flows. In summary, banks can effectively support large and mature companies, and the larger the company, the more innovative it is.[30] Banks under the highly centralized financing model can centralize financial services and resources to serve the real economy, as evidenced by their support for the catching-up strategies of non-leading countries and their moves to improve the innovation capabilities of large companies. Banks, especially large banks with substantial funds, are best suited to provide support for large companies and groups in order to utilize centralization to mitigate vertical risks in the organizational transformations of industrial sectors.

8.4.2 Leading Innovation Requires the Capital Market, Especially a Booming Equity Investment Market

Small companies play a more important role in mitigating horizontal risks as they are more willing to promote leading innovation. Banks are willing to offer financing services to companies with collateral. Small companies in many cases do not have

[29] Sato, Yoichiro. “The Industrial Policy Debate Minus Public Relations: Depoliticizing the History of Semiconductor Industry Development in japan. ” *JAPAN STUDIES REVIEW VOLUME FIVE* (2001): 61.

[30] ZHOU Li’an, and LUO Kai. “Corporate Scale and Innovation: Empirical Evidences from Chinese Provinces.” *China Economic Quarterly* 004.003(2005):623–638.

sufficient collateral. In addition, leading innovation is likely to disrupt expectations around companies' cash flows, which we think may dampen banks' willingness to support leading innovation. The reason behind the US leadership in the global semiconductor industry chain is that Apple and many other US companies that are willing to promote leading innovation helped bring about the creation of a new phase in the internet era. The establishment and development of many of these companies was supported by booming US capital markets. The capital market is essentially a highly fragmented investment and fundraising system. Investors with different risk appetites directly make decisions on fund supply to provide capital support for different high-risk projects. Effective support for leading innovation requires positive interactions between primary and secondary markets. The primary market plays a main role in promoting leading innovation, and the ample financial resources in the secondary market can help companies improve their innovation and industrialization capabilities for new products and new industries. More importantly, the secondary market is one of the most important channels for divestment for equity investors in the primary market, and it can improve equity investors' investment capabilities and willingness to invest. Positive interactions between primary and secondary markets can promote leading innovation, in our view.[31]

8.5 Thoughts and Implications: A Dual-Pillar National System

Overall, the key to utilizing centralization to mitigate vertical risks lies in leveraging the advantages of large companies and other groups in catch-up innovation, moves that require financial support from centralized banking systems with substantial funds. This form of organization is the large companies and large banks-based organizational model in this book. Utilizing diversification to mitigate horizontal risks is more reliant on the efforts to tap the potential of diversified consumption to boost demand, move some mature production capacity to Southeast Asia and surrounding countries to increase regional cooperation along industry chains, and build a sustained "China-surrounding countries" technological cooperation model. Such efforts require financial support from diversified capital markets. This form of organization is called the "SMEs and capital markets-based" organizational model in this book. These organizational models are not spontaneous, and their formation requires public policies. In addition, a national system that mobilizes the strengths of governments and markets, along with the strengths of financial markets and the

[31] Wies, Simone, and Christine Moorman. "Going public: How stock market listing changes firm innovation behavior." *Journal of Marketing Research* 52.5 (2015): 694–709. CICC Global Institute, CICC Research. Chapter 16: Financing innovation—Capital markets not the only player. Innovation: Keep the Torch Burning (《创新: 不灭的火炬》, Chinese version). CITIC Press Group. 2021.

real economy, is an important mechanism for efforts to cope with security challenges along industry chains.[32] The government plays a different role in each organizational model. For China, we believe the government should build a dual-pillar national system that both catches up and leads. A catching-up national system supports centralized "large companies, large governments, and large banks", and a leading national system supports diversified "SMEs, system construction, and capital markets". Large banks and companies in China are mostly state-owned enterprises (SOEs). As a result, governments can play an important role in centralization, and banks need to increase the effectiveness of policy-based finance. In a leading national system, the diversification, competition, and "natural selection"-based market mechanism plays a key role in making leading innovation possible, and we think that governments should build market systems that are conducive to free transactions and full competition. Overall, public policies are of great significance to catching-up and leading national systems. A dual-pillar national system is a necessary condition, rather than a sufficient condition, for the moves to resolve vertical and horizontal security challenges along industry chains. To cope with security challenges, efforts should be made to resolve the following four issues related to the two pillars.

First, boundaries between governments and markets: Traditional national systems generally help resolve security issues regarding the supply of public goods. Security of industry chains is related to the interests of a country. However, the key to maintaining the security of industry chains lies in the moves to mitigate supply risks related to consumer products. Both the supply and demand sides of public goods are public sectors, having equal positions in negotiations. However, those on the demand side of industry chains are mostly individual consumers, and companies should be the suppliers as they are equal to consumers in negotiations.[33] One main difference between a dual-pillar national system that is built to mitigate security challenges along industry chains and traditional national systems is that the former should give full play to companies. Designing a suitable market-based incentive plan to stimulate companies is of great importance to the moves of coping with security challenges, as centralization may push up internal organizational costs.

Second, the metrics of monopoly and competition: Centralization, including vertical and horizontal integration, may see large companies increase their market share and expand their presence to multiple industries. Consideration should be given to contestability in order to understand the antitrust issue and the problem of disorderly expansion of capital amid deglobalization. To judge if there is a disorderly expansion of capital, we think efforts should be made to assess if moves to expand

[32] XIE Chao, and LI Tongyue. Research on the National System of Science and Technological Innovation in the US Based on the Comparison between the US and Soviet Union. August 2022.

[33] Ibid.

into multiple industries are supported by forces external to the markets[34] (such as integration of financial business and industrial sectors) rather than paying attention to the number of industries in which companies expand their presence. In terms of the antitrust issue, we do not think that the size of companies and their market share are the only metrics to judge if a monopoly exists. The most common method of judging whether a monopoly exists is to see if corporate integration is followed by monopolistic conduct that hinders competition. More importantly, diversified competition is not just the key to dealing with horizontal risks, but even within large centralized enterprises, it is also an important means for maintaining dynamism in an organization.

Third, relationships between large and small companies: Large companies taking the lead in sectors facing vertical risks is a more efficient method of mitigating such risks. However, it is not a must for large companies to continue to operate businesses in these sectors after they mitigate vertical risks. The social benefit–cost ratios should be the determining factors in deciding if large companies should continue to operate these businesses. A vertically integrated organizational structure may need to be vertically disintegrated after vertical risks are mitigated, and efforts should be made to create an ecosystem that is conducive to small companies innovating and forming new businesses and that helps small companies undertake businesses that are split off by large companies. Demand from large companies plays an important role in supporting small companies' leading innovation. In China, SOEs are mostly large companies, and non-state-owned enterprises are generally small companies. The close relationships between large and small companies in a dual-pillar national systems mean that SOEs and non-state-owned enterprises should establish solid partnerships.

Fourth, which of the two pillars is more important, and which should be prioritized? China is still catching up, and mitigating vertical risks is a top priority. As such, we think a centralized, catching-up pillar for "large companies, large governments, and large banks" is of greater importance in the short term. In the long term, we believe the efforts to build a diversified pillar for "SMEs, system construction, and capital markets" is more important. However, it may not be appropriate to build a catching-up pillar first, then build a leading pillar after mitigating the vertical risks. Vertical risks have attracted more attention, while horizonal risks have also arisen in renewable energy, home appliances, and other industries. More importantly, once a system is established, it will be strengthened by people who benefit from the system unless this system is exposed to intense external forces. In an indirect financing-dominated financial system, China should not only propel the simultaneous construction of the two pillars, but also accelerate the construction of the leading pillar under the principles of the separation of financial business from industrial sectors, and the separation

[34] "Forces external to the markets" means that some economic entities gain influence and control beyond the level of market competition.

of various financial sub-sectors from each other,[35] due to systems' path dependence and the need to achieve leading innovation in the global market in the future. Moves to accelerate construction of the leading pillar conform to the requirement of the 20th National Congress of the Communist Party of China that the country "will increase the proportion of direct financing".[36]

[35] For more details on finance restructuring under the two principles, please read Chapter 16: A Two-pillar Financial System and a Good Society. Building an Olive-Shaped Society (《迈向橄榄型社会》, Chinese version). CITIC Press Group. June 2022.

[36] Source: http://www.news.cn/politics/cpc20/2022-10/25/c_1129079429.htm [Chinese only].

Chapter 9
Improving Supply Chain Ecosystem to Cope With Industry Chain Risks

Abstract Global supply chains (GSCs) originate from the optimization of core enterprises' allocation of factors and resources of production on a global scale. Compared with the research on industry chains, which usually takes a macro perspective, research into supply chains is at a micro level and emphasizes companies' own management decisions. In this chapter, by looking at corporate decision-making from a micro perspective, we analyze the industry chain risks faced by Chinese companies amid the reshaping of GSCs, and examine how to improve China's supply chain ecosystem.

Keywords Supply chain disruptions · Global supply chain · Supply chain finance · Logistics · Transport

Against the backdrop of the COVID-19 pandemic, geopolitical events, and green transition, we believe GSCs will be reshaped amid the trends of diversification, regionalization, digitalization, and green transition. The impacts of COVID-19 and geopolitical factors have led to more frequent GSC disruptions. Therefore, companies now pay more attention to the resilience and robustness of their supply chains. Meanwhile, the trend of green transition also affects the operating costs of companies along the supply chain. As such, companies have begun to reassess their GSC presence while pursuing diversification, regionalization, digitalization, and green transition.

Chinese companies are important participants in GSCs. Share of foreign-invested enterprises (FIEs) in China's total import and export merchandise trade value reached 39% in 2020,[1] and the proportion of foreign and Hong Kong SAR, Macao SAR, and the Taiwan region of China invested enterprises' revenue was particularly high in the automobile sector (53%) and the computer, communication, and electronics

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[1] https://www.gov.cn/xinwen/2021-01/14/content_5579875.htm [Chinese only].

CICC Research, CICC Global Institute, *The Reshaping of China's Industry Chains*,
https://doi.org/10.1007/978-981-97-1647-0_9

sector (47%).[2] By participating in the international value chain led by multinational enterprises (MNEs), Chinese companies and MNEs are suppliers and purchasers of each other's products, and China has become an important node of GSCs.

Amid the reshaping of GSCs, Chinese companies along the GSC face industry chain risks associated with industrial relocation and supply chain disruptions. Given the decentralized layout of GSCs and trends such as reshoring and friend-shoring in GSCs, Chinese companies located in the upstream segments face the risk of industrial relocation of foreign investments (i.e., foreign companies moving their supply chains away from China). Moreover, the current external environment has increased the vulnerability of upstream segments in GSCs, and downstream Chinese companies face higher risks of supply chain disruptions.

A sound supply chain ecosystem can help companies cope with industry chain risks, but China's supply chain ecosystem has yet to be improved in three aspects, i.e., logistics, capital flow, and information flow. In terms of logistics, China's domestic business-oriented logistics has low efficiency, and its international logistics system is relatively weak. As for capital flow, due to the high carrying costs of Chinese companies and the low efficiency of fund flows in supply chains, it is difficult for traditional supply chain finance (SCF) to help companies confront external shocks. In terms of information flow, a large number of Chinese companies are in the early stages of digital transformation of their supply chains. They still need to further promote digitalization to keep up with the development trend in the digital economy era.

China can improve its supply chain ecosystem from the three above-mentioned aspects to cope with industry chain risks amid the reshaping of GSCs. In terms of logistics, China needs to break down barriers in domestic logistics, seize core international logistics nodes, and improve its comprehensive capabilities in overseas logistics services. In terms of capital flow, the financial institutions-led SCF model should play its role in achieving policy goals, and SCF led by core enterprises shall be utilized in an appropriate manner. In terms of information flow, the use of 5G, artificial intelligence, and cloud computing technologies in the digital economy era will significantly optimize companies' operating efficiency and reduce their decision-making costs, thereby increasing supply chain surplus.

[2] Source: National Bureau of Statistics.

9.1 GSCs to Be Reshaped Amid COVID-19, Geopolitical Disruptions, and Green Transition

9.1.1 Supply Chain and GSCs

Supply chain refers to a network of various players such as raw material suppliers, manufacturers, distributors, retailers, and end-market customers involved in the production, circulation, and consumption of products or services. For each organization, a supply chain covers all functions needed to identify and satisfy customer needs, such as R&D, marketing, production, distribution, finance, and customer service. **Unlike research on industry chains that focuses on a macro perspective, supply chain management should be viewed from a micro perspective.** An industry chain refers to an interrelated system consisting of companies that produce various products or provide various services through specialization and transactions. Research on industry chains mainly adopts a macro perspective and emphasizes the relationships among economic sectors, while research on supply chains focuses more on how companies can maximize total supply chain surplus through their own corporate management. Supply chain surplus represents the value generated by a supply chain, which is the difference between what the value of the final product is to the customer and the costs the supply chain incurs in filling the customer's request.[3] From the perspective of supply chain management, studying the formation of supply chain surplus can help evaluate the decision-making process of companies.

In supply chain management, three major decisions made by companies affect their supply chain presence. The production process of products can be divided into four levels: Different tasks constitute different occupations, and different occupations make up different stages of production, which ultimately create products.[4] Generally speaking, a single stage of production is performed in one location, but different stages of production can be performed in either one location or multiple locations. Under the framework of supply chain management, companies usually need to make three decisions about the planning of production processes (or suppliers): **First, whether production should be dispersed or concentrated in terms of geographic location.** Companies tend to take advantage of the difference in factor prices in different areas to reduce marginal production costs, which leads to geographical dispersion of production processes; on the other hand, the geographical concentration of production processes can help companies cut communication costs and reduce the risk of supply chain disruptions caused by uncertainties in transportation. **Second, whether production processes should be outsourced or integrated.** Outsourcing can lower companies' cost of investment in the supply chain, while

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[3] Chopra, Sunil, and Peter Meindl. *Supply chain management. Strategy, planning & operation.* Gabler, 2007.

[4] Baldwin, Richard E. "Global supply chains: why they emerged, why they matter, and where they are going." (2012).

integrated production can reduce the cost of coordination and management of each segment in the supply chain. **Third, whether internal management is lean or agile.** A lean supply chain values just-in-time (JIT) manufacturing, which can lower supply chain costs through JIT inventory management. An agile supply chain focuses on quickly responding to customer demand to enhance customer stickiness and drive up customer value, but this comes with higher supply chain costs.

The key to supply chain management lies in product flow, financial flow, and information flow. Supply chains are dynamic, with continuous flow of products, capital, and information among different segments. For any supply chain, customers are the sole revenue contributor, and only end-market customers can provide companies with positive cash flow. All other cash flows represent the exchange of funds within the supply chain, and all flows of information, logistics, and funds incur costs. Therefore, optimizing the management of product flow, financial flow, and information flow is the key to maximizing the total supply chain surplus.

With the cost of international trade declining since the second half of the nineteenth century, MNEs have optimized the allocation of factors and resources of production, leading to the formation of GSCs. GSCs refer to companies' supply chain designs on a global scale, including the cross-border purchasing of raw materials and intermediate goods, the global layout of production processes, and the global sales of products and services in the era of economic globalization. Multinational enterprises (MNEs) are typical participants in GSCs. Since 1966, standardized containers have been used in the global shipping industry, greatly improving logistics efficiency and reducing logistics costs. The construction of purpose-designed container terminals increased the productivity of dock labor from 1.7 tonnes per hour to 30 tonnes per hour.[5] MNEs began to optimize the allocation of factors and resources of production globally as the substantial improvement in international transport efficiency reduced the cost of international trade, leading to the formation of GSCs.

GSCs improve production efficiency, but they also bring uncertainties. Although globalized production has led to a decline in companies' total production costs, it has also prolonged the cycles and response time of logistics, financial flow, and information flow in supply chains, increasing the complexity of supply chain management. **In recent years, unexpected events such as the COVID-19 pandemic and geopolitical disruptions, as well as the transition to a circular economy have led countries to pay more attention to uncertainties brought by GSCs, triggering discussions on the reshaping of GSCs.**

[5] Bernhofen, Daniel M., Zouheir El-Sahli, and Richard Kneller. "Estimating the effects of the container revolution on world trade." *Journal of International Economics* 98 (2016): 36-50.

9.1.2 Reshaping of GSCs Amid the Backdrop of COVID-19, Geopolitical Disruptions, and Green Transition

International transportation costs rose sharply amid the COVID-19 pandemic; companies have suffered losses due to supply chain delays. Container freight rates have risen to historic highs since 2020, and the overall freight rate has increased by 2–3 times from the pre-pandemic level.[6] When freight rates were at their peaks, the freight-rate-to-cargo-value ratio increased substantially. Since 2H20, the volume of international maritime transport has soared and has been concentrated at core US ports. This has resulted in port congestion, causing a sharp increase in freight rates, and severe supply shortages due to supply chain delays. For example, shipping goods from China to the west coast of the US by sea, which usually took around 20 days, took as long as 47 days (in January 2022) during the COVID-19 pandemic. According to the *World Development Report 2020* released by the World Bank, for many goods traded in GSCs, a day's delay in supply chain cycle is equal to imposing an additional tariff by one percentage point. Although freight rates dropped notably in 2H22, we believe average freight rates are unlikely to return to the pre-pandemic low level in the future as shipping alliances and environmental concerns may dampen the momentum for shipbuilding and promote the scrapping of old ships. Even if freight rates decline, companies still need to reconsider their risk management measures given their exposure to potential freight rate risks.

Trade frictions continue; weight of geopolitical factors in supply chain decision-making has increased significantly. Since the emergence of US-China trade frictions, the weight of geopolitical factors in supply chain decision-making has gradually increased, including political (policy) risks and tariff costs, among others, driving a shift in companies' goal of supply chain management from a sole focus on efficiency to a dual focus on efficiency and security.

Companies have begun to pay more attention to the resilience and robustness of their supply chains given the impacts of the COVID-19 pandemic and geopolitical factors, which may change the layout of GSCs. The "resilience" of supply chains refers to the ability of organizations and supply chains to plan for, respond to, and recover from disruptions in a timely and cost-effective manner. In contrast, "robustness" is the ability to maintain operations during a crisis.[7] Amid the impacts from the COVID-19 pandemic and geopolitical factors, GSCs have suffered from a larger number of disruptive factors, along with rising risks of supply chain fragility and fracturing. Faced with increasing uncertainties in the external environment, companies may change the global layout of their supply chains in order to enhance the resilience and robustness of their supply chains. **In addition, green transition has increased companies' production costs and further promoted**

[6] Pulido, José. *Pandemic-induced increases in container freight rates: Assessing their domestic effects in a globalized world*. No. HEIDWP24-2022. Graduate Institute of International and Development Studies Working Paper, 2022.

[7] Baldwin, Richard, and Rebecca Freeman. "Risks and global supply chains: What we know and what we need to know." *Annual Review of Economics* 14 (2022): 153–180.

the reshaping of GSCs. Green transition and carbon emissions reduction have become international consensus. Many countries have set schedules for reaching peak carbon emissions and achieving carbon neutrality, and raised carbon emission costs and environmental standards for companies. At the international level, the EU may take the lead in implementing carbon tariffs, imposing higher tariffs on carbon-intensive imports to guard against carbon leakage. The promotion of green policies may alter the comparative advantages of developing countries, thereby affecting total supply chain costs and further promoting the reshaping of GSCs. We analyze four trends in the reshaping of GSCs in the next section: Diversification, regionalization, digitalization, and green transition.

9.1.3 Development Trends of GSCs: Diversification, Regionalization, Digitalization, and Green Transition

From the perspective of corporate decision-making, GSCs are undergoing changes in geographic locations, production processes, and internal management. At the geographical level, MNEs may redesign their supply chains by reshoring, nearshoring, and friend-shoring. **In terms of production process**, core enterprises will likely enhance supplier management, such as requiring suppliers to use clean energy; in addition, some companies may strengthen R&D to pursue integrated production instead of external procurement in the face of high risks of supply shortages for certain products. **As for internal management,** the applicability of lean management has declined. Factors such as information lag and time lag in logistics tend to have a bullwhip effect on supply chains, i.e., small fluctuations in demand at the retail level can cause progressively larger fluctuations in upstream segments, making it more difficult for upstream companies to anticipate demand and manage inventories. Lean management was widely adopted by companies during the rapid expansion of globalization. In the absence of external impacts, lean management under the low-cost and low-inventory model can ensure stable business operations. However, if external shocks occur, the bullwhip effect would make it difficult for suppliers to predict downstream customer demand, and lean management would limit suppliers' ability to respond quickly to customer demand, causing upstream suppliers to lose revenue due to lack of inventory.

Overall, we see four trends that are shaping the future of GSCs: Diversification, regionalization, digitalization, and green transition.

1. **Diversification means that the goal of supply chain management will shift from a sole focus on efficiency to a dual focus on both efficiency and security.** Considering the possibility of supply chain disruptions and uncertainties in delivery, companies may have to strengthen the robustness and resilience of supply chains at the expense of cost and efficiency, with a greater level of redundancy and fragmentation in supply chain management. Amid the COVID-19 pandemic, supply chain disruptions have become more prominent due to the

concentration of supply chains. Therefore, we think companies may consider diversifying their supply chains and adding alternate suppliers for important products to avoid risks arising from concentrated supply chains. Due to limited room for supply chain reshoring, companies are more likely to reduce supply chain risks by adjusting safety stock and adding alternate suppliers (usually in regions close to existing supply chains or sales territories).

2. **The impact of soaring freight rates during the COVID-19 outbreak may prompt companies to relocate their supply chains to nearby regions and shorten the physical length of supply chains, implying growing regionalization of supply chains.** The long physical length of a supply chain tends to bring additional security risks such as the bullwhip effect caused by disruptions to GSCs amid COVID-19. Also, we believe that companies may consider, among other factors, establishing a presence in nearby regions and shortening shipping distance to reduce supply chain costs.
3. **Digital technologies are reshaping the form of supply chains.** Digital transformation of supply chains has become technologically feasible. Amid the background of Industry 4.0, the application of digital technologies such as Internet of Things (IoT) is reshaping the form of supply chains. Meanwhile, supply chain disruptions caused by external shocks such as the COVID-19 pandemic create urgent needs for digitalization of supply chains. The risk of supply chain disruption underscores the importance of the visibility and controllability of information, prompting more companies to pay more attention to omni-channel management. Therefore, companies are likely to significantly increase investment in supply chain digitalization in the future, and Supply Chain 4.0—the next-generation digital supply chain—will likely be put on the agenda.
4. **Russia-Ukraine conflict has accelerated the green transition of supply chains.** The Russia-Ukraine conflict that broke out in 2022 has increased uncertainty in the supply of traditional fossil energy, and countries in Europe are accelerating decarbonization of energy systems. European countries such as Germany and Italy rely heavily on energy imports from Russia. Data from British Petroleum shows that imports accounted for 39%, 77%, and 59% of the EU's coal, crude oil, and natural gas consumption in 2020, and most of the imports were from Russia.[8] Although it is unlikely for Europe to end its dependence on Russian energy in the near term due to the high cost of switching to alternative energy suppliers, the Russia-Ukraine conflict has raised the strategic importance of developing renewable energy to a new height, which may accelerate the global energy transition and drive the decarbonization of supply chains.

[8] Source: Federal Customs Service of Russia, IEA.

9.2 Chinese Companies Have Been Deeply Involved in GSCs

9.2.1 MNEs Facilitate the Formation of GSCs

MNEs are organizers of and participants in global industry chains and supply chains, and play an important role in international economic and trade. In 2014, MNEs' headquarters and foreign affiliates contributed 33% of global output, 28% of global GDP, 23% of global employment, 55% of international exports, and 49% of international imports.[9] Since the 1980s, increases in foreign direct investment (FDI) and foreign outsourcing led by MNEs has made the network of GSCs increasingly complex. At the end of the twentieth century, the information technology revolution reduced the coordination cost across regions, making it feasible to spatially separate production processes.[10] Meanwhile, given varying labor costs in different countries, companies in developed countries can substantially reduce product costs and increase profit margins by locating production processes in developing countries. Therefore, as organizers and participants in supply chains, MNEs keep high-skill stages of production such as R&D and design in their home countries, and carry out low-skill activities such as manufacturing and assembly in developing countries. This represents a typical model of vertical specialization in which high-skill stages of production are located in developed countries and labor-intensive production stages in developing countries.[11] From the perspective of globalization, such specialization led by MNEs can boost the exports of manufacturing countries, and enables companies in these countries to directly or indirectly integrate themselves into GSCs by providing input products and outsourced services.

MNEs' activities in China have accelerated China's integration into GSCs. Since the 1990s, the deepening of China's market-oriented reforms and its demographic dividend have prompted MNEs to enter China, and China has thus become deeply involved in GSCs. Through FDIs, MNEs undertake labor-intensive stages of production such as processing and manufacturing in China, then export finished products from China to overseas retail markets, making China the world's most important manufacturing hub amid rapid increases in export value. FIEs accounted for 59% of the total trade value between the Chinese mainland and its trade partners in 2006, and this proportion remained high at 39% in 2020.[12]

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[9] Cadestin, Charles, et al. "Multinational enterprises in domestic value chains." (2019).

[10] Baldwin, Richard E. "Global supply chains: why they emerged, why they matter, and where they are going." (2012).

[11] Cadestin, Charles, et al. "Multinational enterprises and global value chains: New Insights on the trade-investment nexus." (2018).

[12] Ministry of Commerce. Statistical Bulletin of FDI in China 2021.

9.2.2 Technological Development of Chinese Companies Has Led to Gradual Withdrawal of Foreign Investment From Low-Tech Industries in China

At present, companies receiving direct investments from foreign countries, Hong Kong SAR, Macao SAR, and the Taiwan region of China are mainly concentrated in the east coast of China; among manufacturing industries, foreign and Hong Kong SAR, Macao SAR, and the Taiwan region of China invested enterprises (hereafter referred to as FIEs for brevity in subsection 8.2.2.) enjoy advantages in the automobile and computer & communications industries. In 2020, they accounted for 11% of the number of manufacturing enterprises above a designated size in China.[13] They were concentrated in coastal provinces due to their focus on exports in their early stages of development. FIEs accounted for 24% of the total revenue of all manufacturing enterprises above a designated size.[14] In particular, the proportion was as high as 53% in the automobile sector and 47% in the computer, communication & electronics industry, while the proportion of revenue from the primary product processing industry was low.[15]

For enterprises above a designated size, FIEs have been gradually exiting less-profitable sectors while strengthening their presence in highly profitable sectors. The proportion of FIEs in the number of all enterprises above a designated size in China fell from 18% in 2011 to 11% in 2020, and the proportion of operating revenue at FIEs dropped from 26 to 22%, but the proportion of their operating profit increased from 25 to 27%.[16] Operating revenue of FIEs in the manufacturing industry in the past decade has increased while their number has decreased, and more foreign investors have exited low-tech industries. Over 2011–2020, the number of FIEs declined in most sectors, with sharp declines in medium- and low-tech segments such as textiles & apparel, wood processing, and leather products, indicating FDI outflows from these fields. In high-tech sectors such as transportation equipment manufacturing and special equipment manufacturing, the number of FIEs has increased or declined by a milder margin in 2011–2020. In terms of operating revenue, the average revenue of industrial FIEs that stayed in China expanded markedly in most manufacturing sectors. Over 2011–2020, the average revenue of industrial FIEs rose from Rmb380mn to Rmb570mn, implying an average annual growth rate of 4.6%. By contrast, during the same period, the average revenue of all industrial enterprises above a designated size in China only grew from Rmb260mn to Rmb270mn, at an annual growth rate of 0.5%.[17]

There are multiple reasons why MNEs are gradually exiting low- and medium-tech industries and becoming larger and stronger in industries in

[13] Source: Ministry of Commerce.

[14] Source: National Bureau of Statistics, China Industrial Statistical Yearbook.

[15] Source: National Bureau of Statistics.

[16] Source: National Bureau of Statistics.

[17] Source: National Bureau of Statistics.

which they have advantages. First, technological diffusion has caused MNEs to lose excess profit in low- and medium-tech sectors. Many domestic companies have developed the technological capabilities to compete with foreign companies in low- and medium-tech fields. Through market competition, profit margins of some foreign companies have been reduced, causing foreign companies with weak technological capabilities to exit the market, while other foreign companies with better technological capabilities can grow larger and stronger. **Second, rising labor costs in China** have pushed some MNEs to leave China and choose to expand their presence in other low-cost countries. Rising labor costs have a more significant impact on total costs in low-tech and labor-intensive industries, hence the greater number of FIEs exiting from these industries in China. In addition, as external factors such as **geopolitics and COVID-19** pose challenges to the resilience and robustness of GSCs, some MNEs are choosing to reduce their reliance on production networks in China and are dispersing their supply chain networks in different regions. We will elaborate on this later in this section.

9.2.3 Chinese Companies and MNEs Are Suppliers and Purchasers of Each Other's Products

As specialization improves efficiency and as companies have their own production boundaries, final products are generally produced by multiple companies, thus forming a supply chain network with companies at the nodes. We refer to the organizers and leaders of the supply chain network as **core enterprises.** Moreover, enterprises in a supply chain network play two roles: downstream purchasers and upstream suppliers. **From a supply chain perspective, Chinese companies can serve as both upstream suppliers and downstream purchasers to MNEs.** First, Chinese companies can integrate themselves into MNEs' upstream supply chains as direct (tier-1) or indirect (tier-2 or other tiers) suppliers. MNEs have a large presence in the automobile and electronic products sector among manufacturing industries. For example, the Shanghai Gigafactory established by Tesla has enabled some Chinese companies to become its upstream suppliers due to the strong regional patterns of the auto value chain. Second, as China is the world's largest manufacture hub, Chinese companies need to purchase raw materials and intermediate goods from MNEs in order to complete downstream production. Among the major global MNEs we track,[18] according to FactSet, four of the top 10 MNEs with the highest revenue contribution from China in 2021 were in the raw materials industry (Fortescue Metals Group, BHP Billiton, Rio Tinto, and VALE) and four were in the information technology industry (LG Display, MPS, Qualcomm, and Texas Instruments), reflecting

[18] Major global MNEs are mainly listed companies included in the MSCI World Index. Data for revenue contribution from the Chinese mainland represents FactSet's estimates, mainly based on the latest annual reports released before the end of 1Q22.

Chinese companies' great reliance on upstream resources purchased from overseas companies.

Chinese companies have been deeply involved in GSCs. Above all, China is an important node in GSCs. Given China's factor endowments and industrial support, MNEs have actively established supply chains in China, and a large number of Chinese companies and foreign MNEs have become suppliers and purchasers of each other's products. In addition to the two roles of suppliers and purchasers, some Chinese companies have grown into multinationals and play a role in GSCs as organizers. For example, by setting up overseas R&D or production centers, Chinese companies such as Huawei and Xiaomi have been allocating resources globally and building their GSC networks.

9.3 Risks of Industrial Relocation and Supply Chain Disruptions Caused by the Reshaping of GSCs

9.3.1 China's Industry Chain Risks Brought by Supply Chain Reshaping Amid the COVID-19 Pandemic, Geopolitics, and Green Transition

As the COVID-19 pandemic disrupts GSCs, reshoring, or reducing the presence of supply chains in China may be alternative options. Since 2H20, rising demand for imported consumer goods in Europe and the US, coupled with insufficient shipping dispatch capacity and a shortage of cargo handling personnel at ports, have led to poor container turnover and an insufficient supply of shipping capacity.[19] This has caused GSC disruptions and delays, pushing up the Global Supply Chain Pressure Index (GSCPI) to a historic high (Fig. 9.1). As China is a global production powerhouse for numerous manufactured products (including medical protective equipment), supply chain disruptions triggered by the COVID-19 pandemic have made it difficult for European and US companies and consumers to obtain Chinese products they need in a timely manner. Therefore, in order to ensure a long-term and stable supply in domestic markets, some companies may adjust their supply chains via reshoring, nearshoring, and supplier diversification.[20]

Geopolitical factors have triggered technological decoupling, product boycotts, and rising trade costs, weighing on international supply chains' presence in China. Geopolitical factors affect Chinese companies directly in multiple ways, such as bans on domestic companies from trading with Chinese companies, boycotts of Chinese products, higher import tariffs, and imposing of export controls on China. In response to domestic public opinion and policy requirements, MNEs

[19] https://unctad.org/news/shipping-during-covid-19-why-container-freight-rates-have-surged

[20] Miroudot, Sébastien. "Reshaping the policy debate on the implications of COVID-19 for global supply chains." *Journal of International Business Policy* 3.4 (2020): 430–442.

Fig. 9.1 Global Supply Chain Pressure Index (GSCPI) has been rising since the COVID-19 outbreak. *Note* The GSCPI is used to provide a summary of potential supply chain disruptions, and it is based on a variety of international transportation cost indices and Purchasing Managers' Indices (PMI) of seven major global economies *Source* Federal Reserve Bank of New York, CICC Research

may need to remove Chinese suppliers or downstream Chinese customers from their supplier or customer networks in a targeted way (e.g., the US Entity List). In addition, in the face of higher import barriers, enterprises may shift some of their stages of production away from China to target market countries for their products. Moreover, as companies in various countries need to carry out procurement globally, risks at other nodes of the GSC network triggered by overseas geopolitical events, such as regional disruptions in logistics and production, may also indirectly affect the supply chains of domestic companies.

Green transition increases companies' production costs; enterprises raise management requirements on their suppliers. China's energy consumption is dominated by traditional energy sources, while green transition requires an increase in the use of clean energy, which add to the production costs of Chinese companies. Some enterprises have proposed carbon neutrality requirements for their entire supply chains. For example, Apple plans to achieve carbon neutrality for its entire supply chain by 2030, urging its suppliers to adopt clean energy[21]; Huawei has incorporated carbon emission reduction requirements into its supplier management process.[22]

9.3.2 Upstream Chinese Companies Face Risk of Industrial Relocation

Amid the reshaping of GSCs, MNEs may diversify their supply chains away from China and accelerate industrial relocation (i.e., foreign companies move

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[21] www.apple.com/hk/en/newsroom/2021/10/apple-charges-forward-to-2030-carbon-neutral-goal-adding-9-gigawatts-of-clean-power-and-doubling-supplier-commitments/

[22] https://www.cnii.com.cn/gxxww/rmydb/202205/t20220525_383426.html

their supply chains away from China), affecting upstream suppliers in China. (1) Impact of COVID-19 pandemic and green transition: MNEs may relocate part of their production capacity out of China and diversify their production sites in order to guard against supply chain disruptions caused by natural hazards such as the COVID-19 pandemic. Also, given the COVID-19 pandemic and green transition, MNEs have imposed higher requirements on supply chain design and supplier management, and some Chinese suppliers that do not meet environmental standards or have weak responsiveness to market changes may be removed from their supply chains. **(2) Impact of geopolitical events:** Since the emergence of US-China trade frictions, core companies have resorted to reshoring, friend-shoring, and nearshoring in order to avoid import tariffs on specific Chinese products. Meanwhile, the frequent global geopolitical events and the chain reactions of GSCs may prompt some MNEs to relocate their supply chain networks to their home countries. According to a Kearney survey in 2022,[23] the value and proportion of manufactured goods in the US imported from China declined over 2018–2021, while the proportion of imports from other low-cost Asian countries like Vietnam (friend-shoring), and from Mexico (nearshoring) increased.

To confront the risk of industrial relocation, China can unleash domestic demand to continue to attract foreign investment. We believe foreign MNEs in China mainly adopt two strategies for business development: (1) The "World's Factory" strategy (relying on Chinese factories to produce goods that are ultimately sold elsewhere); and (2) the "In China for China" strategy (aiming to provide products or services for the vast, growing China market). Given rising labor costs and MNEs' tendency of reducing production and procurement in China due to external impacts, China, as the world's factory, may become less attractive to FDIs, and some stages of production may be relocated away from China. However, China's large demand can provide a buffer, and the country may continue to attract FDIs aiming to serve the domestic market.

In fact, the majority of MNEs in China have started to shift from the "World's Factory" strategy to the "In China for China" strategy. The solid financial returns of their businesses in China are the main reason why FDIs are staying in China. Over 1998–2013, micro-level data of China's industrial enterprises[24] showed a downward trend in the proportion of FIEs' sales to overseas regions, which means more FIE products are being sold to the China market. According to a survey by the American Chamber of Commerce in Shanghai, 53% of the surveyed companies in China adopted the strategy of "In China for China" in 2021, another 12% aimed to export products to China, and only 18% of the companies surveyed in China adopted the "World's Factory" strategy.[25] Among S&P 500 companies, the profit margins at the top 50 companies with the largest revenue contribution from businesses in China have continued to outperform those of other companies without overseas business since 2010, and have surpassed those of the top 50 MNEs with the largest proportion

[23] Kearney. The tides are turning—The 2021 Reshoring Index. April 2022.

[24] China Industrial Enterprise Database, constructed by National Bureau of Statistics of China.

[25] 2021 Business Climate Survey by AmCham China.

of revenue from overseas businesses since 2016.[26] This implies that MNEs in China have been shifting towards high-end business with increasing operating revenue in the past decade, and they have been gradually exiting low-tech and low-profit-margin sectors; in addition, MNEs with a high proportion of business in China have posted high profit margins, reflecting that the Chinese market is able to generate good financial returns, which is the main reason why FDIs have been entering China and staying there.

9.3.3 Downstream Chinese Companies Face the Risk of Supply Chain Disruptions

Chinese companies in the downstream segments of GSCs are facing greater risks of supply chain disruptions and delays as the external environment has increased the vulnerability of upstream supply chains. First, COVID-19 and climate change may cause global or regional production and logistics disruptions, affecting upstream suppliers of Chinese companies. Second, geopolitics may increase uncertainties in the supply of key raw materials and intermediate goods. Foreign suppliers may directly cut off supply to Chinese companies or delay product delivery; foreign governments may put restrictions on exports to China. **In addition, as China is deeply integrated into GSCs, the complex international environment may also have an indirect impact on Chinese companies.**

Chinese firms need to pay attention to industry-specific supply chain risk factors that may recur or have long-term impacts, and formulate risk response plans. Some conventional risk management measures can help companies reduce the risk of supply chain disruptions, including increasing inventory, adding standardized modules, improving logistics efficiency, and diversifying suppliers.[27] When faced with supply chain disruptions, companies have different solutions for the short and the long term. For example, Japan imposed export controls on semiconductor materials bound for South Korea in 2019. As the production of relevant materials is highly concentrated at Japanese companies, and photoresists (labile) and hydrogen fluoride (highly toxic) cannot be stockpiled in large quantities, South Korean companies tend to respond by increasing purchases from alternative suppliers and overseas Japan-invested companies in the short term. However, from a long-term perspective, South Korea may choose to improve its domestic production, including investing in the R&D of domestic companies and introducing foreign companies to set up factories

[26] HE Lu, LI Qiusuo, and WANG Hanfeng. Foreign-invested Enterprises in China Amid Changes Unseen in a Century. June 20, 2022.

[27] Chopra, Sunil, and ManMohan S. Sodhi. "Reducing the risk of supply chain disruptions." *MIT Sloan management review* (2014).

Chopra, Sunil, and ManMohan S. Sodhi. "Managing risk to avoid supply-chain breakdown." *MIT Sloan management review* (2004).

in South Korea (in particular, South Korea has made rapid progress in domestic production of hydrogen fluoride).[28]

9.4 China's Supply Chain Ecosystem Needs to Address Three Issues in Response to Industry Chain Risks

Amid the reshaping of GSCs, Chinese companies face the risks of industrial relocation and supply chain disruptions, threatening the security of industry chains. It is thus of vital importance to address these issues. Industry chain security mainly refers to the ability of supply chains to maintain resilience and robustness in the face of external shocks. Therefore, China needs to build a sound supply chain ecosystem and give companies in supply chains more flexibility in decision-making so that they can quickly adjust the allocation of factors of production when facing changes in the external environment in order to maintain the relatively sustainable and stable ability to obtain supply chain surplus. **A sound supply chain ecosystem can help companies improve their supply chain management capabilities, enhance the resilience and robustness of their supply chains, and also ensure industry chain security.** Successful supply chain management requires effective control over logistics, capital flow, and information flow. However, various problems in persist in China's current supply chain ecosystem, and there is still room for Chinese companies to improve their supply chain management capabilities.

9.4.1 Efficiency of Domestic Business-Oriented Logistics Has Yet to Be Improved; International Logistics System Still Weak

Due to the low efficiency of business-oriented logistics, logistics costs in China are relatively high, implying large room for improvement compared with the US. China's overall logistics costs in absolute terms and as a percentage of GDP are both higher than those in the US. According to the Ministry of Transport of the People's Republic of China, logistics costs in China stood at Rmb16.7trn in 2021, accounting for 14.6% of GDP, while logistics costs in the US were Rmb12trn (or US$1.85trn) over the same period, accounting for 8.0% of GDP. At present, the efficiency of China's consumer-oriented logistics is ahead of other countries. For example, the operational efficiency of JD.com's "Asia No. 1" Warehouse is similar to that of Amazon's warehouses in terms of daily delivery volume, sorting efficiency, and accuracy. However, business logistics efficiency remains low in China. Data from

[28] https://cn.nikkei.com/industry/itelectric-appliance/49012-2022-06-30-05-04-00.html?start=1, https://zh.cn.nikkei.com/industry/itelectric-appliance/43756-2021-02-09-04-59-20.html?start=1, https://www.reuters.com/article/south-korea-chip-solutions-0708-mon-idCNKCS1U4054

Wind shows that inventory turnover days of manufacturing sectors in China and the US averaged 83 and 67 days in the past five years, with that in China 23% higher than the US. Therefore, the crux of the problem of China's higher logistics costs mainly lies in the low efficiency of business-oriented logistics.

Low efficiency of business-oriented logistics in China is mainly dragged by low automation rate, low transportation efficiency, and low proportion of integrated transportation. First, the automation rate of China's logistics is low, averaging 20% in 2019 (vs. 80% in developed countries)[29]; in 2019, modern warehousing and logistics facilities accounted for 7% of total facilities area in China (vs. 22% in the US).[30] Second, China's logistics has low transportation efficiency, with the percentage of empty miles standing at about 40% in 2019 (vs. only 10–20% in developed countries).[31] Third, the proportion of integrated transport is low. The proportion of rail-sea intermodal transport at Chinese ports was only 2.6% in 2020 (vs. 20–40% in developed countries).[32] **Improving business logistics efficiency can strengthen the comparative advantages of China's supply chains.** At present, China may maintain advantages in per-unit logistics cost in the near term thanks to the large number of employees in the logistics industry. However, as the demographic dividend weakens, China's logistics costs may face further upward pressure. If business logistics efficiency can be improved, China's logistics costs are likely to decline, which could reduce the total costs of companies' supply chains in China and enhance China's comparative advantages in supply chains compared with other countries with low wages, thus helping Chinese companies cope with supply chain risks.

In addition, China's international logistics system is still weak, which is unlikely to support Chinese companies in overseas expansion or global procurement, mainly due to three factors. (1) Insufficient distribution of core logistics nodes and resources: As of January 2021, there were about 185 all-cargo aircraft in China, only about one-tenth that of the US (about 1,125).[33] China's transport capacity for international routes has yet to be improved. (2) Weak door-to-door services: International logistics services need to cope with institutional and cultural differences in different regions and countries, while Chinese logistics companies lack capabilities in cross-border shipping, order fulfillment, and delivery in overseas regions. For the international express delivery business, foreign companies still play a dominant role in the global market. (3) Weak pricing power: The pricing power of international logistics is related to that of imported and exported goods, and logistics companies can barely determine the price of logistics services on their own. Moreover, Chinese companies have limited presence in the nodes of the international logistics network, which also makes it difficult for them to gain pricing power in the logistics market.

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[29] Source: MIR Databank.

[30] Source: Cushman & Wakefield.

[31] Source: Ministry of Transport.

[32] Source: Ministry of Transport.

[33] Source: Planespotters.

9.4.2 *Inefficient Fund Flow Makes It Difficult for Traditional Supply Chain Finance to Cope With External Shocks*

The high carrying cost of Chinese companies weighs on the efficiency of fund flow in supply chains. During the daily operations of companies in supply chains, their working capital is mostly tied up in the forms of prepayments, inventories, and accounts receivable, leading to tight cash flow and putting pressure on their capital turnover. The cost of such working capital is mainly represented by carrying cost. Carrying cost refers to all expenses incurred during the flow of goods from the original resource supply to the end-market customers (excluding transportation expenses and administrative expenses), including explicit costs such as warehousing and packaging fees, and implicit costs such as capital tied up and damaged goods.[34] Carrying costs are higher in China's supply chains, and lower in the US's supply chains. Inventory turnover days of the manufacturing industry in China averaged 83 days in the past five years, 23% higher than in the US (67 days). In 2021, China's logistics value of industrial goods totaled Rmb299.6trn. Given the inventory turnover days of China's manufacturing industry (76 days) and the weighted average interest rate of corporate loans (4.6%) in 2021, the cost of capital tied up during the logistics process was about Rmb2.5trn in 2021, accounting for 45% of the carrying costs that year.[35] Accelerating the capital turnover of companies in supply chains can help reduce their operating costs and improve the stability of their operations, thereby enhancing the resilience of China's supply chain ecosystem.

An important way to improve the efficiency of fund flow and reduce carrying cost is to utilize SCF instruments. In order to meet the financing needs of enterprises in supply chains, relevant financial products are created. Financial institutions can provide enterprises at different stages of production and operation along the supply chain with different supply chain finance (SCF) products, such as: (1) Confirming warehouse financing, goods pledge financing, and order financing in the order placing and purchasing stage; (2) warehouse receipt pledge financing and inventory pledge financing in the inventory carrying stage; and (3) accounts receivable pledge financing and accounts receivable discounting in the sales and payment collection stage. SCF services emerged earlier in foreign countries. Factoring was already common in Western countries centuries ago; and inventory financing services were prevalent in the US in the nineteenth century; in addition, warehouse receipt pledge rules were also established in the US in the early twentieth century.[36] These are common traditional SCF services and are also prevalent in China at present.

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[34] Defined by the National Development and Reform Commission and the National Bureau of Statistics.

[35] Source: Wind.

The actual portion of capital occupancy cost may be less than 45%, as this calculation method uses the annual cumulative circulation value.

[36] HU Yuefei, and HUANG Shaoqing. "A Study of Supply Chain Finance: lts Economic Background, lnnovation and Concept." *Journal of Financial Research* 000.008(2009):194–206.

However, traditional pro-cyclical SCF may amplify external shocks to supply chains and exacerbate supply chain instability. One of the disadvantages of traditional SCF[37] is its high pro-cyclicality during macroeconomic cycles, which may prevent SCF from coping with external shocks to supply chain security, and may even amplify such shocks to supply chains. The pro-cyclicality is characterized by: (1) The credit expansion of financial institutions that inject a lot of liquidity into the market during economic upturns, which may result in asset bubbles and an overheated economy; and (2) a decline in lending activities by financial institutions during economic downturns or in the face of negative external shocks, which may in turn exacerbate the negative impact on the economy. It is worth noting that companies often tend to have poor cash flow during economic downturns or in the face of negative external shocks. However, for the reason of risk control, financial institutions may reduce lending to companies impacted by economic cycles. For example, the economic fluctuations in 2H19 weighed on the business operations of China's small and medium-sized enterprises (SMEs), increasing the probability of SMEs defaulting on their loans. As such, financial institutions reduced the size of loans issued to SMEs to varying degrees,[38] adding to the pressure on SMEs.

9.4.3 Digitalization Penetration Rate Has Yet to Be Improved

Chinese companies are still in the early stages of digital transformation. For example, the global average penetration rate of industrial digitalization was 23.5% in 2019, with Germany having the highest penetration rate at 45.3% vs. only 19.5% in China. Although China's penetration rate of industrial digitalization increased to 21% in 2020, it is still much lower than that in developed countries.[39] According to iResearch, a large number of Chinese companies are still in the early stages of supply chain digitalization. Relevant supply chain digitalization products are not widely used by Chinese companies at present as they do not have a full understanding of its advantages. Promotion of supply chain digitalization and relevant education marketing are still underway.[40] Also, many companies cannot directly purchase digital transformation solutions for their entire supply chains due to limited budgets.

Digital transformation can improve the accuracy of demand forecasts for supply chains and help companies cope with external shocks. In the digital economy era, the key to information flow management of supply chains is to

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[37] Traditional supply chain finance mainly refers to supply chain finance that operates in a market-oriented manner, and is differentiated from supply chain finance that has been dominated by core enterprises with the development of fintech in recent years.

[38] China Federation of Logistics & Purchasing. Comments on "Smart supply chain and finance": How can supply chain finance help SMEs get out of trouble in the face of COVID-19?

[39] China Academy of Information and Communications Technology. White Paper on China's Digital Economy Development. 2021.

[40] iResearch. 2022 China Supply Chain Digitalization Report. 2022.

strengthen data accumulation and to analyze data using algorithms such as deep learning. In particular, amid COVID-19 and geopolitical impacts, the use of big data and cloud computing technologies can enhance the accuracy of forecasts regarding changes in demand, thereby mitigating supply chain risks. For example, during the COVID-19 pandemic, Macy's predicted the decline in consumer demand by mining credit card data, and controlled its inventory level in a timely manner. Compared with its rival Kohl's, which saw inventory increase 48% YoY in 2Q22, Macy's inventory increased only 7% YoY in the same period, easing the firm's pressure of destocking (most US department stores suffered from destocking pressure in 2H22).[41] Therefore, digital transformation may help Chinese companies improve the resilience and robustness of their supply chains.

9.5 Thoughts and Implications

The COVID-19 pandemic, geopolitical events, and green transition have triggered the reshaping of GSCs. As such, Chinese companies are exposed to the risks of industrial relocation of foreign investments and supply chain disruptions. China's large market potential has prompted MNEs in China to shift toward an "In China for China" strategy to serve the domestic market, which can mitigate the risk of industrial relocation to a certain extent. In addition, changes in the external environment may imply more frequent natural hazards such as pandemics and extreme weather, as well as geopolitical events in the future, leading to more supply chain disruptions. Therefore, China needs to build a supply chain ecosystem with strengthened capabilities to cope with external shocks. We elaborate on the construction of China's supply chain ecosystem from three perspectives: Logistics, capital flow, and information flow.

9.5.1 Breaking Down Barriers in Domestic Logistics and Building an International Logistics System

Internally, breaking down barriers in domestic logistics can help establish a unified market across China, thereby optimizing the distribution and coordination of factors of production and reducing China's industry chain risks. First, China needs to break down barriers in inter-regional logistics coordination. In order to establish a unified large market, China could encourage the development of cross-region professional logistics service providers with a comprehensive logistics network, remove the tangible or intangible barriers among regions, and avoid inefficient use of logistics resources while strengthening economies of scale.

[41] Wall Street Journal. How Macy's Has Avoided — So Far — the Inventory Pileup Plaguing Other Apparel Chains. October 2022.

Second, China needs to break down logistics barriers and strengthen coordination between different modes of transport. Different means and modes of transport have their respective strengths and applicability. Enhancing cooperation and coordination between different means of transport is an important way to improve overall transport efficiency. China's transport structure still has large room for improvement due to constraints such as industrial structure and inconsistent transport standards. In the future, strengthening the role of railways in transport and developing multimodal transport will be vital to the transformation of the transport structure.

Externally, China needs to upgrade its international logistics system by seizing core supply chain nodes and resources and improving integrated logistics service capabilities. First, China shall accelerate the obtaining of core supply chain nodes and resources. The acquisition of overseas warehouses and shipping capacity, which represent the core resources that play an important role in boosting efficiency and safety in logistics networks, should be prioritized. Warehousing resources are irreplaceable in certain transport scenarios, and overseas warehouses will likely become key infrastructure as the supply chains of cross-border logistics mature. Meanwhile, some logistics companies with integrated capabilities may accelerate overseas acquisitions, thus driving industry consolidation and a transition from extensive growth in the past two years to high-quality consolidation for overseas warehouses. In addition, we see significant upside potential in China's international shipping capacity resources (cargo aircraft and ships). For example, the proportion of domestic transportation of imported goods in Japan reached 70–80% in 2006,[42] while the proportion of oil transported domestically in China was only 30% in 2019.[43] **In addition, China could cultivate international logistics companies which can shoulder the responsibility of helping domestic goods going global.** Judging from the history of United Parcel Service (UPS) and Federal Express (FedEx), the rise of US cross-border logistics companies is complementary to the global expansion of US companies. FedEx has gradually established a global logistics service network through acquisition of existing facilities and building new ones, and to a large extent helped US multinationals achieve globalization by leveraging its reliable fulfillment capabilities and cost-effective logistics services. Chinese logistics firms also need to grow into international supply chain companies to support Chinese companies' global expansion.

9.5.2 Leveraging the Benefits of Supply Chain Finance in a Proper Manner

Improving supply chain security requires greater policy support for SCF. SCF led by financial institutions refers to the traditional and most commonly used SCF model, in which financial institutions provide financing services for companies in

[42] http://paper.people.com.cn/zgnyb/html/2016-01/04/content_1645401.htm [Chinese only].

[43] Source: Public announcement of Cosco Shipping Energy Transportation Co., LTD.

the upstream and downstream segments of the supply chain by controlling the fund flow, logistics, and information flow in the supply chain. The traditional SCF model is highly pro-cyclical, and is unlikely to play an effective role in confronting shocks to supply chain security, but may instead become an amplifier of shocks. This means that policy support for SCF needs to be enhanced in order to improve supply chain security.

Leveraging the SCF model led by banks and other financial institutions to achieve policy goals. Banks are the most important source of funding supply for SCF in China, where the major large banks are state-owned. From the perspective of ensuring supply chain security, it is necessary to give full play to the role of SCF led by financial institutions in achieving policy goals. Compared with other funding sources for SCF, the transaction value of direct financing by banks was the largest in China, reaching Rmb44.9trn in 2021 and accounting for about 75% of that of all funding sources in the past five years.[44] When faced with external shocks, companies in supply chains tend to see a decline in their operating cash flow. However, banks can help companies that are vulnerable in the supply chain ensure normal business operations and maintain supply chain security by increasing their cash flow from financing activities.

A new SCF model dominated by core enterprises has emerged. To ensure supply chain security, in addition to SCF led by financial institutions, attention should be paid to the SCF model led by core enterprises, and this model should be utilized properly. With the development of supply chains and financial markets, some core enterprises in supply chains, including large warehousing and logistics companies or technology platforms,[45] have started to provide funds and other financial services for upstream and downstream enterprises, creating a new SCF model led by core enterprises.[46]

Based on their respective professional advantages and market positioning, core enterprises can obtain key information such as prices, orders, and goods in the

[44] Source: People's Bank of China, China Banking and Insurance Regulatory Commission, China Securitization Analytics, Commercial Factoring Expertise Committee of CATIS, Factoring Committee of China Banking Association.

[45] It is stipulated in the *Opinions on Promoting Regulated Development of Supply Chain Finance in Support of Stable Circulation, Optimization and Upgrading of Supply Chains and Industrial Chains (2020)* issued by the People's Bank of China and seven other government departments that "financial institutions, core enterprises, warehousing and logistics enterprises, as well as technological platforms, should focus on their main businesses, enhance sharing and cooperation based on their professional advantages and market positioning, and deepen information synergy and technological empowerment. Efforts should be made to develop more scenario- and ecosystem-based SCF."

[46] In a narrow sense, core enterprises generally exclude warehousing and logistics companies and technology platforms. However, these two types of enterprises play a crucial role in supply chains in terms of segments such as production and services, and they tend to expand into financial services on the back of their own businesses (different from the SCF model dominated by financial institutions). Therefore, we refer to the two types of enterprises and core enterprises (narrow sense) together as core enterprises (broad sense) in the following parts of this report.

upstream and downstream segments of the supply chain, and leverage their or financial institutions' advantages in capital to provide SCF financial services. Core enterprises generally conduct the SCF business in two ways: (1) Setting up their own commercial factoring companies, financial leasing companies, micro-loan financing platforms, and investment and financing platforms; or (2) cooperating with commercial banks or other financial institutions. This model has grown along with refined production, convenient logistics, and large-scale operation of conglomerates, and has become prevalent in foreign countries. For example, General Electric (GE) provides its customers with asset-based lending and equipment financing services through GE Capital.[47] There are also many such financial practices in China. SF Express offers accounts receivable factoring, bill discounting, and other services to its suppliers through a financial service subsidiary[48]; JD.com provides financial products such as prepayment financing, accounts receivable financing, and bill discounting for small, medium, and micro enterprises, as well as merchants on JD.com's platform.[49]

Under the new SCF model, core enterprises have a better understanding of the operations of companies in the supply chain and can play an effective role in ensuring supply chain security. The SCF model dominated by core enterprises has neither government guarantees nor funding sources from the public. Instead, it relies on internal financial services to support the financing of companies in the supply chain. In addition, compared with the financial institutions-led SCF model, core enterprises-led SCF can reduce information asymmetry and help mitigate the pro-cyclicality of the financial sector as core enterprises have a better understanding of the operations of companies in the supply chain than financial institutions do. Therefore, to overcome financing constraints, policies could provide some room for SCF practices led by core enterprises to play an appropriate role under the premise of legal compliance, in our view.

9.5.3 Seizing Opportunities From the Digital Economy in Supply Chain 4.0

More available and easy-to-use digital technologies can help address the issues of some industries in China that are labor-intensive, costly, and poorly managed. For example, the traditional logistics industry is labor-intensive (however, China's demographic dividend is disappearing), and it is a fragmented market with low penetration of digital and information technologies. In the digital economy era, technologies such as 5G, AI, and cloud computing will likely significantly optimize logistics companies' business processes and operations.

China may reduce the need for industrial relocation through investing in Supply Chain 4.0 and strengthening supply chain management to reduce risks.

[47] https://www.ge.com/cn/b2b/capital

[48] Source: Official website of SF Holdings Group Finance Co., Ltd.

[49] JD.com's corporate finance platform: https://qyjr.jddglobal.com/.

The increasingly mature cross-border e-commerce model is a typical example of the digital supply chain: Cross-border e-commerce has a short distribution channel and high efficiency, facilitates data sharing along the e-commerce network, and enables brands to sell products directly to international consumers. It has become the top choice for Chinese manufacturers to reach global consumers. Moreover, cross-border e-commerce makes it easier for emerging countries and small- and medium-sized enterprises to become part of the global value chain. Apparel company SHEIN's sales model is an example of the digital supply chain: The firm's average delivery lead time is only 11 days (vs. 30–60 days for ZARA) and it launches more than 10,000 new items per month (vs. only 1,000–2,000 for ZARA). Chinese brands play a more important role in the cross-border e-commerce supply chain than they are in the traditional trade. We expect the emergence of leading companies in the supply chain to enhance the controllability of the supply chain.

Chapter 10
Raw Material Commodities—Supply Risks and Security

Abstract The Russia-Ukraine conflict has dealt a major shock to the global commodity industry chain, which has worsened terms of trade and pushed up inflation, bringing supply chain security to the forefront of international attention. The commodity market is prone to a natural oligopoly, which underlies the supply security concerns among commodity importers. However, historically, countries—including those in Europe as well as the US, have not always been at a disadvantage for their reliance on commodity imports given their market dominance, which can be attributed to their technological and capital strength. Amid intensifying geopolitical conflicts and an accelerating green transition, we explore how a major resource-dependent country like China should build strength in the market to mitigate supply risks and ensure supply security.

The mismatches between demand and supply in China are due to strong demand for resources, high dependence on imports, and high concentration of supply. Such factors constitute the major risks facing China's commodity market, and are further exacerbated by cost disadvantages and slowing technological substitution. Supply–demand dynamics may tighten further amid the evolving landscape of the global commodity market and bring increased uncertainties to China. Resource nationalism refers to government intervention through control and dominance of natural resources within the country's jurisdiction for political and economic purposes) has flared up and competition has escalated among commodity importers as the green transition has tightened supplies and inflated the prices of traditional energy and metals for renewable energy in international markets. Tensions in the international political environment may further fuel resource nationalism, and resource-dependent countries with dominant market power have intensified competition for resources, leading to fragmentation of the global raw material commodity market. China has entered the later stages of industrialization and is pushing forward high-quality development. The country's share of global demand for traditional energy and metals has declined, while demand for new energy metals has increased substantially with low

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demand elasticity. We believe that a resurgence of resource nationalism will result in higher concentration of commodity supply, further amplifying risks.

To cope with the challenges of raw material commodity supply, this report proposes measures at both the industry and national levels based on international experience and domestic reality. At the industry level, we think China could tap its domestic potential while expanding overseas channels, strengthening reserve capacity, and accelerating recycling and technology substitution. At the national level, we think China could continue to upgrade the security of its supply chains for strategic minerals, participate in global cooperation, and safeguard raw material supply chain resilience.

Keywords Raw material commodities · Supply chain security · Resource nationalism · Supply chain resilience

10.1 Supply Security in an Oligopolistic Market

The Russia-Ukraine conflict has been a major shock to global commodity markets since the beginning of 2022. Global energy and food supplies have been disrupted, leading to continued volatility in commodity prices. The economic impact of the disruptions on commodity importers is twofold. First, commodity price volatility has caused imported inflation and possible economic recession.[1] The inflation rate in the Eurozone's 19 countries, the countries most affected by the conflict, rose to 9.1% in August 2022, the highest since records began in 1997. Spain, Portugal, and the UK were among the countries with the highest inflation rates in Europe (Fig. 10.1). Second, volatile commodity prices have worsened terms of trade. In 1H22, terms of trade continued to deteriorate in manufacturing superpowers such as Germany, Japan, and South Korea. Germany recorded its first trade deficit since 1991,[2] while resource-exporting countries such as Australia and Canada saw significant improvement in terms of trade as commodity prices soared. Studies show that price hikes lead to a wealth transfer from resource-importing countries to resource-exporting countries.[3] The stark contrast between resource-importing and resource-exporting countries reflects evolving market power in the international commodity market and its impact on the world economy, foregrounding the vital significance of ensuring secure and reliable supplies of commodities.

In fact, many countries have been paying increasing attention to the security of industry chains, with ensuring reliable supplies of critical resources remaining

[1] ZHANG Tianding, "International Commodity Shocks, Pass-through and China's Inflation Dynamics." *South China Journal of Economics* 9(2014):18.

[2] For more details, please refer to Energy sectors hold the key to exchange rates published by CICC Research on August 11, 2022.

[3] Fried, Edward R., et al. *Higher oil prices and the world economy: the adjustment problem.* Brookings Institution, 1775 Massachusetts Ave. NW, Washington, DC 20036, 1975.

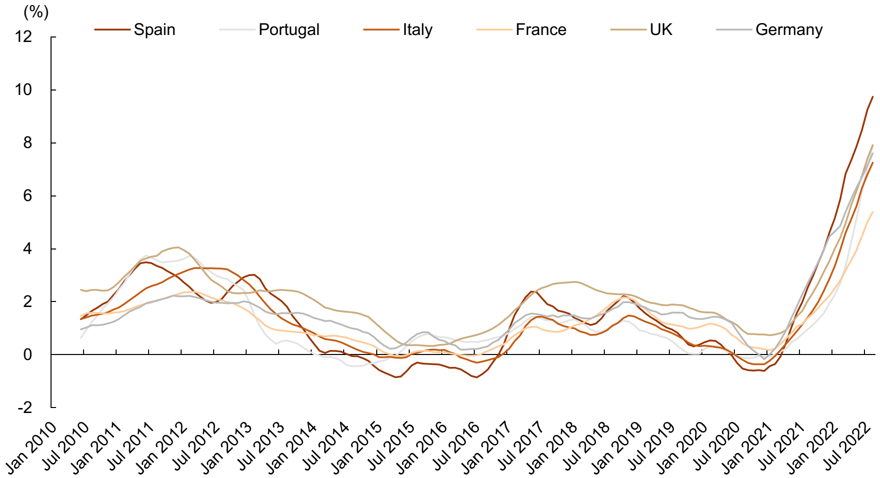

Fig. 10.1 Inflation rates continued to rise in major European countries. *Note* Six-month rolling Consumer Price Index (CPI). *Source* iFinD, CICC Research

one of their core concerns. The Russia-Ukraine conflict has further amplified the geopolitical impact on commodity industry chains. The US, along with its trading partners—including Canada, Australia, and Finland—announced the establishment of the Minerals Security Partnership (MSP),[4] and teamed up with Australia and Japan to develop rare earth projects.[5] These reflect acceleration of Western countries' global commodity deployment.

Resource importing companies are vitally concerned about securing their supply chains because the commodity market is prone to a natural oligopoly, and this underlies the supply security concerns among commodity importers. Classical theories consider a market structure in which there are few sellers selling products that have no close substitutes as an oligopoly. The commodity market happens to meet these two conditions: First, many natural resources are concentrated in a small number of countries due to uneven geographical distribution.[6] Second, the elasticity of demand for upstream raw materials is low as there are few close substitutes.[7] In addition, the long mining and construction cycle of mineral resources always results in a fixed quantity of supply at a given time. The lack of elasticity of supply further strengthens the market power of resource suppliers.

However, demanders were not always disadvantaged by the resource exporter oligarchy as suppliers have not always achieved full dominance in the resource

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4 https://www.state.gov/minerals-security-partnership/

5 https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/us-australia-japan-india-to-collaborate-on-rare-earths-production-8211-nikkei-63123999

6 WTO. Natural resources: Definitions, trade patterns and globalization. 2010.

7 TENG Tai, et al. "Elasticity of Supply and Demand for Global Bulk Commodities." *World Economy Study* 6(2006):6.

market. In fact, they had been in a disadvantageous position between the Age of Exploration until the Industrial Revolution, and the situation persisted following the end of the Second World War. In contrast, European countries, as resource demanders, secured large amounts of low-cost resources such as oil. Even after the Second World War, resource-importing countries—including European countries and the US—maintained control over resources backed by their technological and capital strengths. Strong post-war demand for the reconstruction of Western Europe and Japan as well as economic expansion in North America drove prices higher during the 1950s and early 1960s.[8] This in turn strengthened the control that such countries had over resource supply, leading to an oligopoly dominated by resource-importing countries. History shows that resource demanders have not been particularly disadvantaged for their reliance on commodity imports despite the advantages that suppliers have in market power endowed by a natural oligopoly such as the commodity market.

It is then natural to wonder what determines the market powers of commodities suppliers and commodities demanders. We believe that supply–demand dynamics underlie the distribution of power of buyers and sellers in the commodity market. If the supply–demand dynamics are tight, resource-exporting countries tend to strengthen control, putting sellers in a dominant position. In contrast, buyers may enjoy a stronger position in a more market-oriented trading landscape formed amid loosened supply–demand dynamics.[9] In an oligopolistic market, stronger market power enables a participant to trade in its favor, which is the case for resource-importing countries in terms of ensuring supply security.

Market power also hinges on key structural characteristics of supply and demand such as supply concentration, cost competitiveness, and demand elasticity. In economics, the residual demand curve is used to describe the relationship between a reduction in the output of suppliers in an oligopolistic market and market prices. The slope of the curve represents the market power of the supply-side oligopolist, and is related to the concentration of supply, the gap in supply costs between the firm and its competitors, and elasticity of demand.[10] First, the higher the supply concentration, the easier it will be for sellers to reach open or tacit collusion agreements, and thus the stronger their joint control over market prices. Second, the more competitive the supply costs of an oligopolist, the stronger its market power. This is because when this oligopolist announces a reduction in production, other competitors will have to mobilize higher-cost technologies and resources, making it less likely to quickly and economically fill the gap resulting from the output cuts. Third, the less elastic the demand is, the less likely it will be for supply cuts to cause sharp declines in consumption, thus helping sustain a steady rise in prices.

Political and economic influence on market power is realized by changing concentration of supply. Europe and the US, which have strong political and economic power,

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[8] World Bank. Commodity Markets Book 2022: Evolution, Challenges, and Policies. 2022.

[9] Miras, Manuel. "Elasticity of Supply and Demand and Price Rigidity of Trade Goods." *Journal of Economic Society* (1987).

[10] Goldberg, Pinelopi Koujianou, and Michael M. Knetter. "Measuring the intensity of competition in export markets." *Journal of international Economics* 47.1 (1999): 27-60.

have significant influence in the international raw material commodity market given their high participation in such markets. When the global political and economic landscape changes, competition for raw material commodities will intensify. As a result, the dominant power will be more motivated to increase the concentration of supply of the resources under their control. The Thucydides Trap[11] becomes relevant in this context in which the established leader of market power will leverage its comprehensive strength to secure additional resources and enhance the concentration of supply, thus further amplifying its market power in strategic areas such as raw material commodities.

Technological innovation reshapes market power through demand elasticity and cost competitiveness. Technological innovations can increase elasticity of demand if related to commodity production and demand substitution, but they tend to boost commodity demand and tighten supply–demand dynamics if designed to diversify end-user applications. For example, the development of nuclear power and renewable energy power generation technologies has slashed demand for traditional energy sources and increased demand elasticity, while rising penetration of communication technologies and new energy technologies has boosted demand for materials such as copper, lithium, cobalt, nickel, and glass and reduced demand elasticity.

10.2 Risks and Causation

From a national perspective, commodity supply security is a measure of a country's status or ability to obtain the natural resources it needs in a sustainable, stable, timely, sufficient, and economical manner. It takes into account not only the quantity of supply,[12] but also the economics of obtaining the resources.[13] From the standpoint of countries that import raw materials, we define factors that may cause a complete cutoff of resources as major risks, and define those that incur great costs for resource-exporting countries to ensure security of supply as secondary risks. We use this classification to analyze the risks of raw material commodity supply in China.

10.2.1 Risk Origin: Supply–Demand Mismatch

Global reserves and production of commodities are concentrated in a limited number of countries. North America, Russia, and the Middle East accounted for 70% of the

[11] The Thucydides Trap, a term coined by Graham Allison from Harvard University, is the notion that when a rising power challenges the established leader of the international order, the dominant power will inevitably resort to containment and suppression.

[12] GU Shuzhong, et al. "Conceptual Framework and Research Focus of Resource Security." *Journal of Natural Resources* 17.3(2002):280-285.

[13] WANG Ling, and CHU Zheyuan. "Literature Review on Vulnerability in Supply Chain." *Soft Science* 25.9(2011):4.

global oil production and 63% of natural gas in 2020. In terms of conventional metals, 39% of production of iron ore is concentrated in Australia, 18% in Central and South America, and 11% in China. South America is the world's largest copper producer, with Chile holding 23% of the global copper reserves and Peru 11%. Bauxite production is concentrated in Guinea, Australia, and Brazil. Global lithium reserves are mainly located in South America, Australia, and Africa. The Democratic Republic of the Congo produced 71% of the cobalt globally. Indonesia and Australia each hold 22% of the world's nickel reserves, followed by Brazil (17%).[14] The U.S. Geological Survey (USGS) reports that 90% of globally explored platinum reserves are in South Africa. Concentrated location of reserves and geographic maldistribution of natural resources explain the sharp imbalance between supply and demand across the globe (Fig. 10.2).

The geographic maldistribution has added to supply risks in China's raw material commodity market. China is a manufacturing power, and raw materials play a crucial role in the development of its industry chain, the national economy, people's livelihoods, as well as social and economic stability. China has relatively weak natural resource endowment with low self-sufficiency rates for most categories—i.e., a self-sufficiency rate of less than 10% for copper, cobalt, nickel, and platinum.[15] However, the country has significant demand for resources to develop the industry chain, and its pillar industries such as chemicals, steel, and equipment manufacturing are heavy consumers of resources. China is the largest consumer of coal, accounting for 56% of global consumption in 2020. It also consumed 16% and 9% of global oil and natural gas production, and accounted for more than 40% of global demand for conventional metals (e.g., iron ore, aluminum, and copper) and metals used in new energy technologies (e.g., lithium and nickel). Its share of global consumption of platinum and cobalt reached 26% and 32%.[16]

10.2.2 *Major Risks: High Dependence on Imports; High Concentration of Supply*

China relies heavily on raw material commodity imports, and its export partners are relatively concentrated. It imports most of its raw materials, and the country saw its share of primary commodity imports in total imports continue to increase in recent years due to demand–supply mismatch.[17] Its dependence on oil and natural gas imports reached 72% and 40%, and it imported more than 80% of its metals, including iron ore, copper, and platinum. The country's dependence on importing metals used in renewable energy, lithium, cobalt, nickel, and platinum reached was

[14] Data source: IEA, BP, USGS, corporate filings, CAAM, and EV Sales.

[15] Data source: USGS, corporate filings, CAAM, and EV Sales.

[16] Data source: IEA and BP.

[17] According to the General Administration of Customs, China's import value of primary products has grown at an average annual rate of 3.5% since 2010.

Supply demand ratios	Oil	Natural gas	Coal	Iron ore	Coking coal	Copper	Aluminum	Lithium	Platinum	Cobalt	Nickel
China	0.3	0.6	1.0	0.3	0.9	0.1	2.2	0.4	0.0	0.0	0.1
Europe	0.3	0.4	0.6	0.2	0.2	0.3	-	0.0	-	-	-
North America	1.1	1.1	1.1	0.8	3.6	1.0	-	0.1	0.2	0.0	-
Russia	3.2	1.5	2.7	2.4	1.4	2.2	5.5	-	-	-	7.6
Australia	0.5	3.7	7.6	136.4	-	74.3	578.9	-	-	-	137.9
Middle East	3.3	1.2	0.1	-	-	0.6	2.7	-	-	-	-
Central and South America	1.1	0.9	1.3	10.5	-	23.2	29.5	-	-	-	-
Other regions	0.5	1.0	0.9	1.1	0.7	1.4	17.0	0.8	2.9	3.3	2.9

Fig. 10.2 Mismatch between local commodity supply and end-market demand in major economies and regions (2020). *Note* The data in this figure represents supply–demand ratios, which is local supply divided by end-market demand. The darker the red color, the smaller the supply–demand ratio. The darker the green color, the higher the supply–demand ratio. The data shaded in yellow represent supply–demand ratios in-between. "- " indicates data not available. *Source* IEA, BP, USGS, corporate filings, CAAM, EV Sales, CICC Global Institute

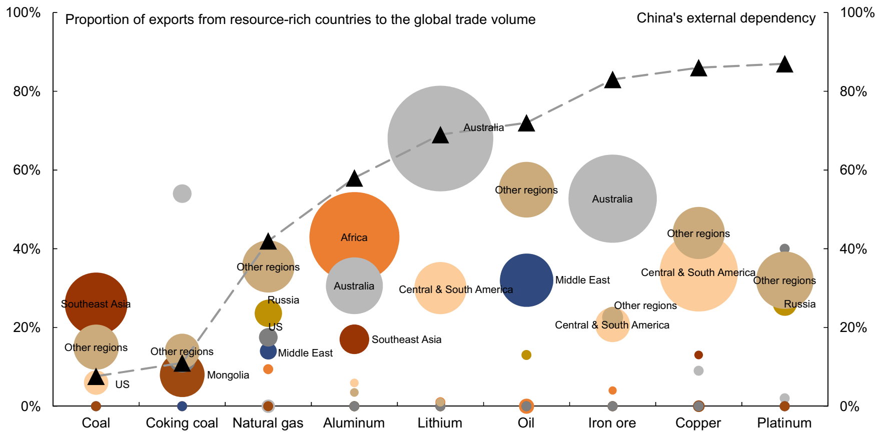

Fig. 10.3 China has high dependence on imports and high supply concentration of raw material commodities (2020). *Note* The size of the bubble indicates China's imports of the product from the selected country as a percentage of its total imports. *Source*: UN Comtrade, World Steel Association, General Administration of Customs, CICC Research

69%, 66%, 98%, and 87% in 2020 (Fig. 10.3)—demand that we expect to continue to rise. China's imports of most categories are concentrated in a few countries: Australia supplies 68% and 61% of China's imports of lithium and iron ore; Chile and Peru combined accounted for 50% of copper imports; and 51% of aluminum imports came from Guinea, with 32% from Australia.

This trade pattern makes the raw material commodity supply in China susceptible to the influence of market power of suppliers, as is confirmed by the history of China's iron ore trade. China is the world's largest consumer of iron ores, which are used in downstream industries such as steel, construction, and automobiles. Two-thirds of China's imports of iron ores are from Australia and Brazil, which are dominated by international mining giants Vale, BHP, Rio Tinto, and FMG. These big four miners are an oligopoly, putting China under considerable pressure from elevated iron ore prices.

10.2.3 Secondary Risks: Weak Cost Competitiveness; Slow Technological Substitution

Weak cost competitiveness means that when prices of imported products are lower than the local production costs in China, domestic suppliers will face higher cost pressure, resulting in increased supply risk. We use China's position in the global cost percentile of major metal categories and the country's share of global production capacity to depict the cost competitiveness of its major metal categories (Fig. 10.4). It

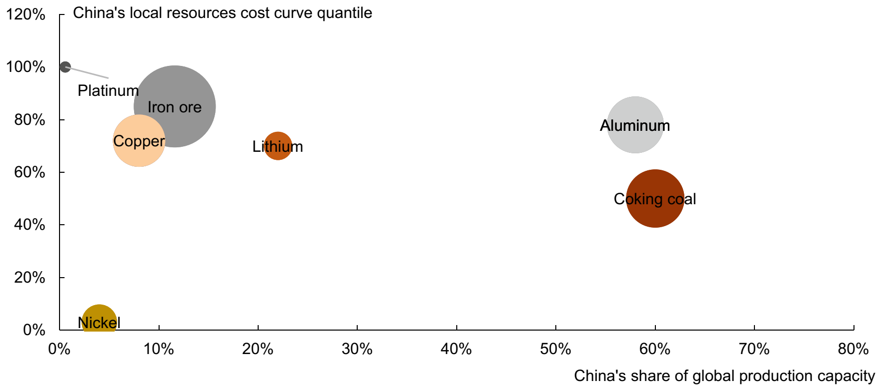

Fig. 10.4 China's metal mineral resources lack cost competitiveness. *Note* The size of bubbles indicates the size of global output value of the selected industry. *Source* USGS, Corporate filings, CAAM, EV Sales, Wind, World Bank, Mysteel, CICC Global Institute

can be seen that except for coking coal, China has high production costs of metals—especially for iron ore—which sits between 80 and 90th percentile of the global supply cost curve. The cash cost of iron ore in China (incl. cost plus freight) is about 2.2 $\times$ that of Australia and Brazil, suggesting significant cost disadvantages for domestically produced iron ores in China. Among metal categories aside from nickel, China stands at the higher end of the global iron-ore cost curve—especially for platinum group metals. The Ministry of Natural Resources reports that the grade of proven platinum ores in China is 0.34 g/t, only one-third to one-fifth of the industrial requirements for ores set by the National Commission of Mineral Reserves and well below the grade of overseas platinum ores.

The feasibility of technological substitution of raw material commodities determines their demand elasticity. If the elasticity of demand is low, resource demanders cannot make timely and effective adjustments to prices amid external shocks, leading to rising supply risks. Theoretically, supply risks of metal ores can be mitigated by recycling and technological substitution. However, China's elasticity of demand remains low given its limited resource accumulation, under-developed recycling system, R&D that lags its global peers, and the country's application of some alternative technologies. Typical examples include iron ore and platinum. Scrap steel can be recycled and substituted for iron ore, but the supply remains insufficient due to limited scrap steel resources in China. Platinum is mainly used in fuel cells and other fields. China may face a shortage of platinum with rising adoption of fuel cell vehicles. However, platinum-based catalysts used in proton exchange membrane fuel cells (PEMFC)—the most popular fuel cell technology—can potentially be replaced by either platinum-reducing or platinum-free products, but breakthroughs have yet to be made. Thus, we believe that this is unlikely to reduce supply risks through technological substitution.

10.3 Evolution of Risks Amid Changing Landscape

Green transition and the shifting international political and economic environment have gradually become the main forces reshaping the landscape of the global commodity market. Green transition has led to tightening commodity supply, sparking a commodity boom. Customary energy shortages drove the penetration rate of renewable energy higher than the market expected. As a result, prices of metals used in renewable energy technologies rallied due to shrinking supply. International political and economic instability intensified global competition for resources. The post-financial crisis world has seen increasing trade conflicts, which escalated amid the COVID-19 pandemic and the Russia-Ukraine conflict. Fluctuations in commodity prices have further prompted economies to pay closer attention to the strategic role of commodities. Resource nationalism has flared up in resource-rich countries, while competition for resources has intensified with an increase in the inclination to stockpile among resource-dependent economies. This has discouraged investment in the international commodity market, which in turn exacerbated price volatility and threatens to create a volatility trap. We believe that mounting internal and external uncertainties necessitate further investigation into the evolving trends of risks.

10.3.1 Risks Amid a Changing International Landscape: Tensions Between Supply and Demand to Intensify

10.3.1.1 Resource-Rich Countries: Resource Nationalism Flaring up Among Top Mining Players

Resource nationalism can take several forms, including nationalizing mineral resources or restricting foreign investment, raising of mineral royalty rates and mining tax rates, terminating or renegotiating existing mining contracts, and banning exports. History shows that the rise of resource nationalism is closely correlated with the global mining boom, as well as the financial position and political environment of resource-rich countries.

We believe the world may be facing a new wave of resource nationalism triggered by mounting fiscal deficits and changing political environments amid the current commodity boom. The 2008 financial crisis left most resource-rich countries financially vulnerable, leading to a powerful wave of resource nationalism. The COVID-19 pandemic since 2020 has further added to the strain on financial distress and public debt. The average overall deficits as a share of GDP in emerging markets in 2022 was visibly higher than pre-pandemic levels.[18] Resource-rich countries in Latin America, the Middle East, and North Africa experienced significant fiscal deficits, and became more inclined to raise taxes on the mining sector to relieve fiscal pressure.

[18] IMF. The Global Financial Stability Report. April 2022.

The impact of resource nationalism spans multiple sectors from traditional energy and metals to emerging strategic minerals. Resource nationalists are shifting their focus from traditional sectors such as oil, natural gas, and copper towards metals used in renewable energy technologies, with new cartel alliances taking shape. Mexico, Argentina, and Venezuela have established their own national oil companies, and Peru Mining Company and Chile's CODELCO are both state-owned. The increasing strategic significance of metals used in renewable energy technologies is making the nationalization of lithium one of the strategic focuses of Latin American governments.[19] Argentina, Bolivia, and Chile are known as the "lithium triangle" as together 56% of the global proven lithium reserves.[20] These three countries are mulling the creation of an OPEC for lithium,[21] which, once formed, we think will intensify tensions between supply and demand and lead to lithium price rally.

10.3.1.2 Resource-Dependent Countries: Geopolitics Accelerating Global Market Divergence

We expect major economies to see a jump in demand for raw material commodities, but such economies tend to rely on highly overlapping resource requirements. This could lead to fiercer competition among resource-dependent countries. The International Energy Agency (IEA) reports that the aggregate mineral demand from clean energy technologies must at least quadruple by 2040 to reach the Paris Agreement goal, with demand growing by more than 40 × for lithium and 20–25 × for graphite, cobalt, and nickel.[22] Thus, it is paramount that governments and industry work to ensure adequate supply of critical minerals. The World Bank also projects that global demand will increase nearly 500% by 2050 given the growing role of critical minerals in the decarbonization of the energy sector, and it expects the competition for strategic minerals to intensify as a result.[23] As part of strategic emerging sectors across China, the US, and Europe, their high-tech industries—including new energy manufacturing, information and communications and digital technologies—share important similarities in their demand for related raw material commodities, especially for lithium, cobalt, nickel, rare earths.

Resource-dependent countries are paying increasing attention to supplies of critical minerals and are competing more intensely for critical resources. They have increased investments in foreign mining projects while strengthening domestic stockpiling to secure access to reliable and sustainable supplies of critical resources. They

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[19] Institute of Latin American Studies at China Institutes of Contemporary International Relations. History of Resource Nationalization in Latin America. January 2022.

[20] Data source: USGS.

[21] https://www.globaltimes.cn/page/202210/1277765.shtml.

[22] IEA. The Role of Critical Minerals in Clean Energy Transitions. 2021. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

[23] World Bank. Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition. 2019.

also regard resource security as strategically important at the national level. We broadly classify the measures that these countries took into two types: First, they forged alliances to lock in raw materials. Second, they exert influence on the flow of raw materials by leveraging their market power along the industry chain. This has aggravated the fragmentation of the international commodity market.

We believe that the US is working with allies such as Australia and Canada to facilitate cooperation on mineral projects. The country is also seeking wider partnerships with resource-rich countries, while increasing its investments in critical mineral sectors in Latin America to strengthen upstream–downstream cooperation across the lithium. cobalt, nickel, and graphite supply chains. More notably, the US and key partner countries—, including Canada, Australia, Japan, South Korea, Sweden, the UK, and the EU—have announced the establishment of the Minerals Security Partnership (MSP).[24] The goal of these raw material supply alliances is to ensure the security of domestic supply chains for critical minerals such as rare earths and lithium when they are in short supply.

The US is also leveraging its market power in the industry chain to influence the flow of raw material commodities, which is dominated by the US, followed by other developed economies. The US intervention in the raw material flow through supply chains is mainly concentrated in industries such as photovoltaic (PV) and new energy vehicle (NEV) batteries. The US bans polysilicon from specific manufacturers. This has prompted PV power station developers and component suppliers in the country to adjust their supply chains and avoid the use of related products to comply with the requirements. Europe followed suit by adding requirements to review of polysilicon supply from specific manufacturers. The US has recently strengthened its control over raw materials used in NEV batteries. In the Inflation Reduction Act of 2022, the country requires that credit for vehicles should meet critical minerals requirement, that is 40% of the raw materials used in NEV batteries that will be put into use before 2024 should be extracted or processed in the US or a Free Trade Agreement country, or recycled in North America.

10.3.2 China's Risks Amid a Changing Landscape

Against the background of the changing landscape of the international commodity market, China's industrialization has also entered a later stage of transitioning to green and high-quality development. This should catalyze changes in the characteristics of commodity demand, which may lead to higher risks. Below, we analyze the characteristics of commodity demand and evolution trend of risks of the traditional energy and metal and new energy metal industries.

[24] https://www.state.gov/minerals-security-partnership/

10.3.2.1 Traditional Energy and Metals: Weaker Bargaining Power on the Demand Side

The consumption intensity of traditional energy and metals is closely correlated with the stages of economic development. International data shows an inverted U-shaped relationship between commodity demand (e.g., energy and metal) and economic growth, and the demand will decline after plateauing at high levels when GDP per capita reaches around US$20,000–30,000. China's consumption of traditional energy and metals remains stable, with new demand as a share of additional global consumption trending downward for some categories, though absolute consumption is still growing. Consumption of iron ore and coking coal experienced negative growth; energy demand growth has remained below 4% since 2012; annual consumption growth of oil has decelerated to below 5%; and coal consumption has largely been in a state of zero growth.[25] Natural gas maintained rapid growth for being cleaner than other energy categories, and China's share in global oil and coal consumption have both shown a downward trend. The decline in China's share in global energy demand has undermined its bargaining power in the global market, bringing additional risks to the stability of supplies and prices of traditional energy.

Historically, the US and Japan have also experienced weakened bargaining power resulting from falling share in global commodity demand in the mature stage of their industrial development. Since 2000, developing countries, including China, have become the core contributor to the increase in global crude oil demand, with the US share of oil demand gradually declining. The negative correlation between US crude oil inventories and global oil prices began to weaken since then, and West Texas Intermediate (WTI) crude oil price became more volatile with its premium over Brent crude rising sharply, signaling dwindling US influence in the global oil market. The liquefied natural gas (LNG) premium in Japan—the largest natural gas consumer in the Asia–Pacific region—remained largely stable over 1990–2008, but the natural gas premium in Japan began to trend upward in 2009 (when China's natural gas demand surpassed Japan's), and rose to a record high after its failed energy transition through nuclear power due to the Fukushima incident in 2011.

10.3.2.2 New Energy Metals: Stronger Control Over Resources on the Supply Side

As part of global green transition, China has vowed to vigorously promote new energy and enhance its manufacturing competitiveness through scaling the industry. However, China's share in global demand for metals used in renewable energy technologies continues to rise as the sector expands—and so does the risk exposure. China imports most of its new energy metals used in renewable energy technologies. The country is more dependent on imports of new energy metals than on imports of traditional energy and metals, and is becoming increasingly so. We expect demand

[25] Except for 2021 when post-COVID-19 demand volatility recovered.

share and dependence on imports of metals used in renewable energy technologies to increase further, driven by expansion of the new energy industry. In a tight seller's market, an increase in demand share implies amplification of supply risks.

At the same time, China lags behind in metal recycling technologies and applications, of which the country has yet to take advantage, to increase the elasticity of demand for new energy metals. The China Nonferrous Metals Industry Association reports that in 2020, recycled metals accounted for around 27.8% of China's consumption of aluminum, copper, zinc, and lead, which is 7.5ppt lower than the global average of 35.3% and a far cry from the 45% average in developed economies. Recycled copper and aluminum account for more than 50% and 70% of copper and aluminum consumed in the US, and 100% of aluminum used in Japan is now recycled. China still lags behind developed economies such as Europe and the US in recycling technologies and networks for metals used in renewable energy technologies including lithium. Low demand elasticity may lead to an increase in metal supply risks in China in the event of a failure to upgrade recycling technologies and strengthen industry deployment.

10.4 Supply Security Plan in Response to the Changing Landscape

Answering the question of how to ensure the security of commodity supply amid a changing landscape in China has become more pressing and challenging in the context of green transition, and an unstable international political and economic environment. Countries and have strengthened strategic assessment of critical raw materials in recent years based on their domestic or regional industrial development needs. Despite similar objectives, strategies undertaken by these regions tend to differ in focus.[26] Although China is large and resources rich with abundant mineral reserves, room remains for domestic exploration and participation in the development of resources in other countries. We believe that China should accelerate and increase the investment in its expansion in the raw material commodity industry chain given current international tensions. Based on domestic supply–demand dynamics and the aforementioned international experience, we present a plan to ensure secure and reliable supplies of raw material commodities in China at the industry and national levels.

[26] Barteková, Eva, and René Kemp. "National strategies for securing a stable supply of rare earths in different world regions." *Resources Policy* 49 (2016): 153-164.

10.4.1 Industry Measures: Five Key Measures

We evaluate the capabilities of managing supply chain risks of various sectors in China's raw material commodity market from five perspectives—i.e., resource collaboration with other countries, domestic exploration, strategic reserve, recycling, and technology substitution. In order of magnitude of the need to strengthen supply risk measures, we see significant room for further domestic exploration of traditional energy (e.g., oil and gas) and copper, and suggest paying more attention to diversifying the source countries of coal imports. We believe that China should increase its recycling of traditional metals (e.g., iron ore, copper, and aluminum) and lithium, and strengthen the security of supply of new energy metals—including platinum, cobalt, and nickel—through deployment and application of alternative technologies as they gradually mature (Fig. 10.5).

First, we believe that China should tap the domestic potential of traditional energy sources further. Importance should be attached to the strategic significance of oil and gas exploitation, and dependence on foreign oil and gas resources should be reduced. Thus, further policy support is needed to boost investment in oil and gas exploration and development, revitalize existing oil and gas blocks, and accelerate the utilization of proven reserves. Supply chain resilience holds the key to supply security in the coal industry as in the oil and natural gas industry, in our view, and control over coal consumption should point to the direction of future development in China given transportation bottlenecks. Thus, we believe that optimizing coal transportation and increasing the supply elasticity of advanced production capacity are superior options to building new production capacity.

Second, we believe that China should expand metal reserves through overseas collaboration. China should learn from historical failures in overseas iron ore investment, in our view, and the country should invest in current or future overseas high-quality mining projects through buyouts or shareholding to acquire an agreed amount

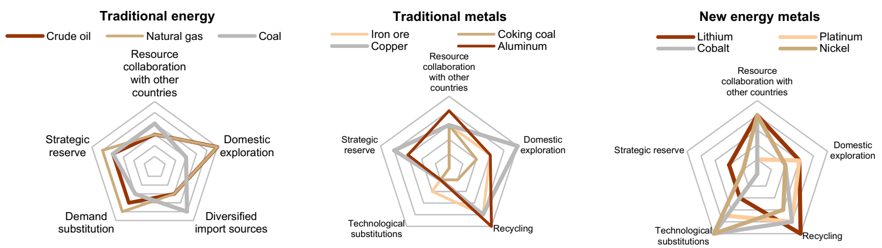

Fig. 10.5 Assessment of capabilities of managing supply chain risks of various sectors in China's raw material commodity market. *Note* Each layer of the pentagon represents a score (1–5). The farther out the layer of the pentagon, the higher the score, signifying a greater need for capability to be strengthened. *Source* USGS, Corporate filings, CAAM, EV Sales, Wind, World Bank, Mysteel, CICC Global Institute

of ore supply or by establishing joint ventures with major ore producers for development of mines. By deepening cooperation with trading partners, we believe that China can secure stable access to resources despite concentrated overseas supply.

Third, we believe that China should build reserve capacity to complement existing resource reserves. China's current commodity reserve system has shortcomings such as overreliance on one reserve method or insufficient reserve capacity. Thus, we believe that China should accelerate construction of a reserve system for critical and strategic resources while increasing reserves of minerals (e.g., oil and copper) as well as new energy metals—especially strategic metal resources.

Fourth, recycling plays a key role in enhancing the elasticity of metal supply and reducing risks. Recycled minerals have a multiplier effect on resource supply,[27] and can add to secondary supply of metal resources while reducing the consumption of primary metals. Metal recycling is environmentally friendly and opens up a new way of ensuring national metal security.

Fifth, technological substitution is a supplementary measure to address the supply shortage of critical categories. The traditional demand analysis of metal mineral resources is based on the premise that no fundamental technological innovation takes place. However, a new round of technological revolution marked by information technology is exerting a significant impact on the demand and supply of metal resources in terms of conservation, substitution, application expansion, and recycling.[28]

10.4.2 National Support: A Two-Pronged Approach

China should continue to upgrade supply chain security for strategic minerals, in our view. Drawing on the experience of developed countries, we think China should create a list of critical minerals in a scientific manner and include the list in the national strategic mineral catalog. The list should be based on comprehensive analysis of supply–demand dynamics and China's ability to ensure reliable and secure supply of the minerals essential in key areas such as new energy, high-end equipment manufacturing, and new-generation information technology. The catalog should be updated dynamically based on factors such as the importance, supply–demand dynamics, and supply risks of the minerals. We believe China should also promote classified management of key minerals. For rare mineral resources such as cobalt and nickel, both domestic resource exploration and overseas cooperation on development should be adopted. China could also accelerate the approval process for release of newly established mining rights, and encourage qualified private capital investment in exploring and developing critical minerals, thereby injecting vitality into the mining market.

[27] GU Yifan, et al. "Coupling Allocation of Primary and Secondary Resources." *China Industrial Economics*5(2016):18.

[28] WANG Chang, et al. "Review and Prospects of National Metal Resource Security." *Resources Science* 39.5(2017):13.

We also believe that China should safeguard supply chain resilience through global cooperation. First, China could build a system to ensure supply chain security along the corridor economies that link supplier countries and consumer countries through high-quality collaboration in the mining industry with the countries of the Belt and Road Initiative. Second, we think China could improve the coordination mechanism for overseas mineral exploration and development, and support mutually beneficial cooperation.

Chapter 11
Chemicals: Commodity Chemicals Industry Shows Strong Competitiveness; High-End Materials Industry Needs Further Improvement

Abstract In this chapter we introduce China's commodity chemicals and fine chemicals & new materials industries, review the driving forces of production capacity transfer as well as the development of representative chemical products, forecast the development trends of the two industries in China, and provide some suggestions for the future development of China's chemicals industry.

Introduction to China's chemicals industry chain: China is one of the world's main producers and consumers of commodity chemicals, and has accumulated relatively strong competitive advantages. In the field of fine chemicals & new materials, new material-based downstream applications have recently emerged in China and the quality of these products is dependent on chemical materials. Currently, the new materials segment in China lacks a development trajectory of trial and error, feedback, technological iteration, and improvement. As a result, most Chinese materials manufacturers are only providing low-end and mid-range products, and the gap between these companies and their overseas peers in high-end materials segment that requires strong R&D and has high added value is large. China still relies on imported semiconductor materials as well as high-end display materials.

Review and outlook for China's chemicals industry chain: We review the three rounds of production capacity transfer in the global ethylene market, and note that demand and cost are the main factors determining the industrial transfer of commodity chemicals once technologies mature. The development of Japan's photoresists and China's mixed crystal industries shows that downstream demand is a growth driver of the fine chemicals & new materials segment, while technological iteration also plays an important role in industrial transfer.

Regarding the development of China's chemicals industry, we expect China to further strengthen its competitive advantages in major commodity chemicals. However, due to trade barriers, rising labor costs, the green transition, and other factors, some commodity chemicals are facing industrial transfer-related pressure. As for the fine chemicals & new materials segment, we believe that the expansion of downstream industries in China could provide a favorable environment for the

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development of fine chemicals and new materials. However, factors such as technical barriers, the technological gap between China and other countries, as well as technological iteration may slow the localization of high-end fine chemicals and new materials. China has competitive advantages in the field of new energy materials, but may also be influenced by protective measures taken by developed economies.

In the field of high-end materials, in which the localization rate is low, China could concentrate on tackling technical problems, increasing efforts to facilitate downstream applications and tests for domestic materials, improving R&D capabilities, and strengthening cooperation and exchanges with overseas leaders. Regarding new energy materials for which China has strong competitive advantages, the country could accelerate the development of new-generation technologies and proactively build factories in developed countries. As for commodity chemicals in which China has gained some advantages, we expect to see green and sustainable development-oriented companies with global competitiveness. For industry chains facing transfer pressure, we suggest accelerating overseas expansion.

Keyword Commodity chemicals · Fine chemicals & new materials · Industrial transfer · Localization

11.1 Introduction to China's Chemicals Industry Chain

Petrochemicals are the main chemical materials and are used in a wide range of industries. The petrochemical sector is a midstream manufacturing industry with a long and complex industry chain. It can be further divided into commodity chemicals and fine chemicals by market size, and area of application. Major raw materials for petrochemicals are oil, gas, and other ores. Oil and gas contain carbon and hydrogen elements, and produce a range of organic compounds. Phosphate, potash, fluorite, quartz, and salt are raw materials of inorganic compounds. Downstream industries for petrochemicals include apparel & textiles, foods, housing, transportation, and many emerging strategic industries. The petrochemical sector plays a crucial role in securing the safe and stable development of China's industry chains.

11.1.1 Commodity Chemicals: China Maintains Competitive Advantages and a Leading Global Position by Output of Most Commodity Chemical Products

China's global market share of commodity chemicals by output and consumption volume is sizable; it has strong competitive advantages. According to the European Chemical Industry Council (CEFIC), chemical sales in China amounted to EUR1.5trn in 2020, representing 44% of the global total, making it the world's largest chemicals market. The growing chemical demand in China accelerated the transfer of production capacity for basic chemicals and general materials to the country. This, together with the engineering bonus and rapid growth of the equipment manufacturing sector in China, has enabled the country to make several breakthroughs in the field of commodity chemicals in the past 20 years.

China has a sizable global market share by output and consumption volume of polyurethane products such as methylene diphenyl diisocyanate (MDI) and toluene diisocyanates (TDI); titanium dioxide; chemical fibers such as polyester filament, viscose, and spandex; basic chemical products such as ethylene oxide, acetic acid, and acrylic acid; and major commodity chemical products such as fertilizers and chlor-alkali. The country has the largest production capacity in the world for most of these products. In addition, China has significant cost advantages on the back of its scale effect, integrated industry chains, and engineering capabilities. With regard to nylon 66, polycarbonate, ethylene–vinyl acetate (EVA), and polyethylene, China still relies on imports and domestic companies are increasing capex to make breakthroughs. As some capacity expansion projects in China start operating, we expect China's dependence on imports to decrease significantly (Fig. 11.1).

11.1.2 Fine Chemicals & New Materials: Improving Industry Chain Security; High-End Materials Are Mainly Imported

There is a large gap between Chinese companies and overseas peers in the high-end fine chemicals & new materials market; China imports products to meet domestic demand. The production of fine chemicals and new materials requires advanced technologies, but in China, advanced application scenarios in downstream industries as well as the supporting equipment are still in the early and middle stages of development. Moreover, China's new materials segment lacks a development trajectory of trial and error, feedback, technological iteration, and improvement.

For downstream companies, the cost of acquiring fine chemicals and new materials is relatively low, but producing their raw materials requires advanced technology. We believe that the fine chemicals & new materials industry is crucial to product quality and to the stable growth of downstream industries, and that downstream companies are not willing to replace existing business partners in the fine chemicals & new materials segment. China's high-end chemicals industry has seen insufficient R&D investment over a long period, and faces challenges from relatively weak independent innovation capability and development of advanced technology. At present, domestic fine chemicals and new materials manufacturers mainly produce low-end products, and the industry is facing fierce competition as well as low added value. There is a large gap between Chinese companies and their overseas counterparts in the high-end fine chemicals & new materials industry, which requires R&D and innovation strengths, and has high added value (Fig. 11.2).

Industry	Product	China's capacity ('000 tonnes)	China's production ('000 tonnes)	Global production ('000 tonnes)	China's share of production	China's apparent consumption ('000 tonnes)	Global consumption ('000 tonnes)	China's share of consumption	China's production/ apparent consumption
PU	MDI	3,420	2,600	7,350	35%	2,354	7,350	32%	110%
	TDI	1,380	1,085	2,510	43%	866	2,510	34%	125%
	Adipic acid	2,680	1,560	3,010	52%	1,265	3,010	42%	123%
Titanium dioxide	Titanium dioxide	4,200	3,512	7,500	47%	2,470	7,500	33%	142%
Chemical fibers	PA6	5,280	3,551	5,921	60%	3,733	5,921	63%	95%
	PA66	555	335	1,836	18%	540	1,836	29%	62%
	Polyester	43,260	34,082	44,640	76%	31,426	44,640	70%	108%
	Spandex	892	708	870	81%	672	870	77%	105%
	Viscose	5,210	3,812	5,209	73%	3,587	52,095	7%	106%
Plastics	PC	1,850	1,100	4,120	27%	2,479	4,116	60%	44%
	EVA	972	756	4,000	19%	1,879	4,000	47%	40%
	PE	23,410	20,020	108,569	18%	38,301	108,569	35%	52%
	PP	28,820	25,816	78,485	33%	31,946	78,490	41%	81%
Basic chemical products	Benzene	16,850	12,600	50,170	25%	14,695	50,170	29%	86%
	Methanol	93,430	68,775	111,040	62%	81,663	111,040	74%	84%
	Acetic acid	9,100	7,753	13,660	57%	7,411	13,660	54%	105%
	EO	5,125	4,020	9,250	43%	4,020	9,250	43%	100%
	Acrylic acid	3,555	2,132	6,360	34%	2,127	6,400	33%	100%
	Sodium carbonate	34,220	27,592	60,280	46%	26,570	60,280	44%	104%
Fertilizers	Urea	69,130	55,918	171,600	33%	50,469	181,300	28%	111%
	DAP	20,820	14,160	48,930	29%	8,431	48,930	17%	168%
Chlor-alkali	PVC	27,125	20,740	49,000	42%	20,898	49,000	43%	99%
	Sodium hydroxide	43,800	35,758	80,000	45%	34,596	80,000	43%	103%

Fig. 11.1 China was one of the world's main producers and consumers of commodity chemicals in 2020. *Note* (1) MDI and TDI are widely used in light industry, textile, transportation, and automobile industries; (2) EVA is widely used in foam in shoes, photovoltaic film, and functional film. *Source* China Petroleum and Chemical Industry Federation, www.oilchem.net, Sci99, Baiinfo, CICC Research

Industry	Sector	Major overseas manufacturers	Major manufacturers in China	Self-sufficiency ratio in China
Semiconductor materials	Silicon wafers	Shin-Estu, SUMCO, GlobalWafers, Siltronic, SK Siltronic	NSIG, TZE, AST Shanghai, AST Chongqing	Low self-sufficency for 12-inch wafers, while self-sufficient for a small portion of 8-inch wafers
	Photoresists	JSR, TOK, Shin-Estu, Sumitomo, Shipley, DOW, etc.	Red Avenue New Materials, NATA OPTO-ELECT, CCEM, Shanghai Sinyang, Suntific Materials	Low self-sufficiency in KrF, ArF, and EUV, while self-sufficient in a small portion of G-line and i-line photoresists
	Electronic grade special gases	Air Products, Air Liquide, Linde, Nippon Sanso, Praxair	Peric, NATA OPTO-ELECT, Yoke Technology, Huate Gas, Grandit Co., Ltd., Linggas	Low self-sufficiency in precursors, self-sufficient in a small portion of film deposition gases and ion implantation products, and partially self-sufficient in etching and cleaning products
	Electronic wet chemicals	Merck, BASF, Ashland, Honeywel, ATMI, Solavy, Arch, Hankel, Kanto, Mitsubishi Chemical, Sumitomo Chemical	CCEM, JHM, Grandit Co., Ltd., DFD, CAPCHEM, Shanghai Sinyang, Greenda	Rely on imports for most of the electronic wet chemicals
	Polishing materials	DOW, CABOT, Fujimi, Versum, Hitachi, etc.	Anji Technology, Dinglong	Rely on imports for most of the polishing pads and polishing fluids
Display materials	Polarizer protective and release film	Zacros, LG Chemical, Toray, Lintec, Mitsubishi Chemical, Nitto Denko, etc.	EMT, etc.	Essentially rely on imports
	TAC film	Fujifilm, Konica Minolta, Hyosung, etc.	EMIS, Lucky, XINLUN, etc.	Japanese companies have 80% market share
	COP film	Zeon, Konica Minolta	None	Rely on imports from Zeon only
	PVA film	Kuraray, etc.	Wanwei Updated High-Tech Material Industry Co., Ltd	Essentially rely on imports
	OCA	3M, Mitsubishi Chemical	SDK, Fineset, XINLUN, etc.	Essentially rely on imports
	OLED materials	Merck, Idemitsu, Doosan, Duksan, Nippon Steel Chemical, Hodogaya Chemical, JNC, DOW Chemical, UDC, LG Chemical, Samsung SDI	Jilin OLED, Valiant, Summer Sprout, Aglaia Tech, PhiChem, LTOM	Currently mainly rely on imports due to constraints from overseas companies' patents
	Polymide film	Dupont, Kaneka, SKPI, UBE, Taimide	RAYITEK, GUOFENG, Times Huaxin, etc.	High self-sufficiency in ordinary grade polymide film, while relying on imports for high-end electronic grade
Other materials	MLCC release film	Lintec, TAK, COSMO, Mitsui Chemical, Teijin, etc.	Jiemei Electronic And Technology Co., Ltd., SXXC, SDK, etc.	Rely on imports for mid- to high-end MLCC release film
	LCP	Celanese, Sumitomo Chemical, Polyplastics, etc.	WOTE, KINGFA, PRET, Ningbo JUJIA	Essentially rely on imports for LCP film
	PPA	DSM, Dupont, EMS, Solvay, etc.	KINGFA, Dezhongtai, Benzo, NHU, WOTE, etc.	Self-sufficient for a small portion of PPA, with a high dependence on imports
	PEEK	Victrex, Solvay, Evonik	ZYPEEK, etc.	Self-sufficient for a small portion of PEEK, with a high dependence on imports
	PSF	Solvay, BASF, Sabic, etc.	Horan, Youju, KINGFA, WOTE, etc.	Self-sufficient for a small portion of PSF, with a high dependence on imports

Fig. 11.2 China's high-end fine chemicals & new materials industry with low localization rate. *Source* SEMI, IHS, China Petroleum and Chemical Industry Federation, 2020 Report on the Development of China's New Chemical Material Industry, CICC Research

There are various types of fine chemicals and new materials, and high-end semiconductor materials directly affect the development of emerging strategic industries. In our opinion, there is still a substantial gap between Chinese companies and overseas leaders in the area of high-end fine chemicals & new materials.

Semiconductor materials: Technological breakthroughs have been achieved for low-end materials, but high-end materials are essentially imported. Benefiting from policy tailwinds and growing demand in the downstream semiconductor industry, many domestic chemical materials manufacturers have expanded into semiconductor materials. However, as latecomers, they face pressure related to patents, skilled workers, and supporting facilities. In addition, the investment period for the semiconductor materials business is relatively long and the speed of technological advancement in the industry is increasing rapidly. As a result, the self-sufficiency ratio in China is low for most semiconductor material products, and imported products still dominate the market for advanced processes, thus weighing on the stable development of the integrated circuit industry chain in China.

For example, in the field of photoresists, the world's most advanced extreme ultraviolet (EUV) photoresists can be used for the production of semiconductor wafers below 7 nm. However, KrF photoresists that have recently started to be mass produced in China are mainly used for 130–250 nm processes, and ArF and EUV photoresists that can be used for advanced processes are still under development (Fig. 11.3).

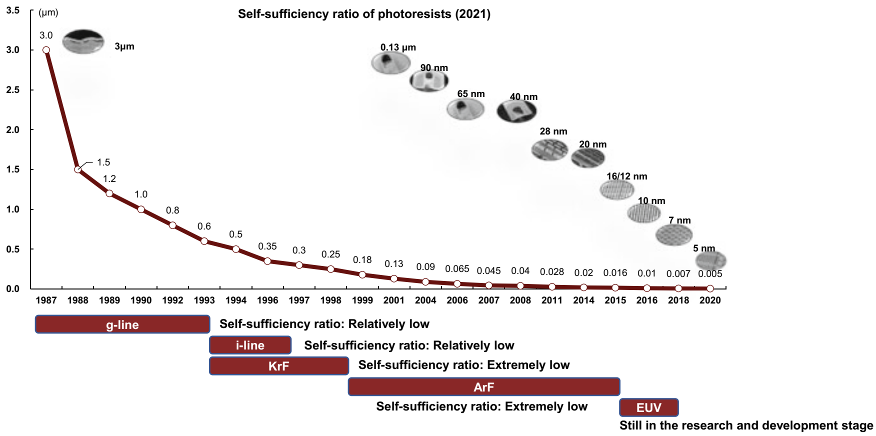
11.2 Review and Outlook for China's Chemicals Industry Chain

In this section, we review the three rounds of industrial transfer in the global ethylene market, as well as the development of Japan's photoresist industry and China's mixed crystal industry. We summarize the main driving forces behind the development and capacity transfer of the commodity chemicals and fine chemicals segments, providing a framework for projecting the potential changes in China's chemicals industry chain.

Commodity chemicals: We review the three rounds of industrial transfer in the global ethylene market, and note that demand and cost are the main forces driving the industrial transfer for commodity chemicals.

Fine chemicals & new materials: We review the development of Japan's photoresist industry and China's mixed crystal industry. We note that the photoresist segment in Japan has high technological barriers, and that materials and formulas continue to change due to technological upgrading in downstream industries. As for China's mixed crystal segment, the barriers to entry are also high, but the speed at which liquid–crystal display (LCD) technologies are being upgraded is relatively slow.

From Japan's experience, we learn that the development of the photoresist industry is correlated with the development of the downstream semiconductor industry. Unlike commodity chemicals, technological factors played an important role during the



Self-sufficiency ratio of semiconductor materials (2021)

Fab materials	Classification	Progress of localization
Silicon chip	6 inches	Relatively high
	8 inches	Relatively low
	12 inches	Extremely low
Photoresists and supporting materials	i-line	Relatively low
	g-line	Relatively low
	KrF	Extremely low
	ArF	Extremely low
	EUV	Still in the research and development stage
Electronic grade special gas	-	Relatively low
Wet electronic chemicals	-	Relatively low
CMP	Pad and slurry	Relatively low

Fig. 11.3 There is still a substantial gap between China's semiconductor material manufacturing technologies and advanced technologies in overseas markets. *Source* Official website of Taiwan Semiconductor Manufacturing Company, China Electronics Materials Industry Association, CICC Research

development of the photoresist industry. During the early stages of development, Japan's photoresist materials industry continued to introduce advanced technologies from the US, and carried out very large-scale integration (VLSI) research nationwide. It successfully narrowed its gap with global leaders. Later, it leaped ahead to be among the top in the world, and related Japanese companies captured growth opportunities brought by the technological upgrading for ArF photoresists, even though the production capacity of the downstream semiconductor industry had shifted from Japan to South Korea, the Taiwan region of China, and the Chinese mainland. Japan maintains its leading position by developing and upgrading supporting facilities for downstream clients.

After the LCD industry upgraded to thin-film-transistor (TFT) liquid crystal displays, Chinese mixed crystal companies saw a large technological gap with its overseas peers. However, they stepped up efforts in R&D and technological accumulation in the field of TFT mixed crystal, and penetrated into the supply chains of downstream panel manufacturers in China. In addition, there was a rapid shift in global LCD panel production capacity to China, which accelerated the localization of TFT mixed crystal.

11.2.1 Commodity Chemicals: Review of the Three Rounds of Industrial Transfer in the Global Ethylene Market and Corresponding Driving Forces

Ethylene is the basic chemical raw material for synthetic plastics (polyethylene and polyvinyl chloride), synthetic fiber, and synthetic rubber, among others. It is also used to prepare styrene, ethylene oxide, acetic acid, acetaldehyde, and explosive materials. According to the CNPC Economics & Technology Research Institute (ETRI), global ethylene production capacity reached around 210mnt and total demand reached around 180mnt in 2021. Ethylene is one of the most in-demand chemical products in the world and is also an important indicator that reflects the progress of development of the petrochemical industry. In our opinion, we can catch a glimpse of the development of the commodity chemicals industry chain by reviewing the changes in and development of the global ethylene industry.

The rise of the ethylene industry in the US. The history of the US ethylene industry can be traced back to the 1920s. At that time, separation of the refinery by-products and ethanol dehydration were the main methods of ethylene manufacturing. However, the scale of production was small and costs were high under these methods. In 1940, ExxonMobil Corporation built the world's first ethylene production unit with refinery gas as the raw material. Following that, raw material categories expanded to naphtha, further enhancing the key position of ethylene in the petrochemical industry. From the 1930s to the 1950s, industrialization was achieved for a variety of vinyl polymers represented by polyvinyl chloride (PVC), high-density polyethylene (HDPE), and low-density polyethylene (LDPE), and the ethylene industry thrived in the US. The global ethylene industry before the 1950s was largely dominated by US companies.

The first round of industrial transfer in the global ethylene market: Low raw material prices and technological upgrading drove the growth of the US ethylene industry. However, the rapid demand growth served as a catalyst that shifted related capacity to Europe. Ethylene production capacity per unit in the US increased significantly from the 1950s to the 1970s as prices of crude oil, which is a major raw material for ethylene manufacturing, were low and production techniques had been optimized. Ethylene production capacity per unit increased to around 500,000t/yr in the 1970s from approximately 50,000t/yr in the 1950s.[1] The US ethylene industry continued to develop in this period on the back of low raw material costs

[1] Cantley, Mark F. "The Scale of Ethylene Plants: Backgrounds and Issues." (1979).

and technological upgrading. However, the rapid growth in demand drove industrial transfer to Europe. Europe's economy grew rapidly from the 1950s to the 1970s. For example, Federal Republic of Germany's GDP grew at a CAGR of nearly 8% over 1950–1960, and the country became the third largest economy in the world in 1960.[2] The development of the European economy accelerated the growth of ethylene demand. As such, the ethylene production capacity of Western Europe accounted for 1.9% of the world's total in 1950, and by 1960, the proportion reached 22%.[3]

The second round of industrial transfer in the global ethylene market: Transfer to Japan and South Korea from Europe and the US was driven by demand growth. The second round of industrial transfer started in the 1970s and ended at the turn of the twenty-first century. Several periods of significant fluctuations in the international crude oil market and a slowdown in economic growth in the US and Europe weakened the growth momentum of their respective ethylene industries. During this period, Japan and South Korea's ethylene industries grew on the back of soaring demand and cost advantages. Since the 1970s, the economies of Japan and South Korea have grown rapidly. For example, the per capita GDP of South Korea increased from less than US$300 in 1970 to US$12,000 in 2000. Production capacity of textile, automobile, and other downstream industries also moved to East Asia from Europe, triggering the growth of ethylene demand in the region. The Japanese and South Korean governments formulated export-oriented economic development strategies. They introduced a series of industrial policies to support the development of heavy chemicals industries represented by ethylene to ensure the supply of raw materials for downstream industries such as the textiles and apparel industry, fueling the transfer of ethylene production capacity to Japan and South Korea.

The third round of industrial transfer in the global ethylene market: Demand growth drove industrial transfer to China. Ethylene output in the Middle East and the US increased due to advantages in raw material costs. The third round of industrial transfer started at the turn of the twenty-first century. During this period, China, the Middle East, and the US saw a significant rise in ethylene production capacity due to rapid growth in demand. During this period, the focus of global economic growth began to shift to China, and production capacity of downstream textiles and automobile industries also moved to China from Japan and South Korea, spurring the growth in demand for ethylene in the country. Meanwhile, China's government rolled out a series of policies to support the development of the domestic ethylene industry and ensure the raw material supply for the textiles & apparel industry, as well as other downstream industries.

The rise in ethylene production capacity in the Middle East and a return to growth for the ethylene industry in the US are mainly driven by cost factors. For example, the "Shale Revolution" in the US boosted the output of shale oil and shale gas. As a

[2] Eichengreen, Barry, and Albrecht Ritschl. "Understanding West German economic growth in the 1950s." *Cliometrica* 3 (2009): 191-219.

[3] LIU He, LIU Yang, and JIN Fengjun. "Research on the Evolution Course,Mechanism and Mode of Global Petrochemical Industry." *World Regional Studies* (2012).

result, the ethylene output in the country grew to 2.5 mn bbl/day in 2021 from less than 1 mn bbl/day in 2010,[4] and ethylene prices dropped to less than US$200/t in 2010–2021 from more than US$400/t in 2007–2010. Stimulated by the sharp decline in costs, US ethylene companies initiated two rounds of capacity expansion. Thus, ethylene production capacity in the US grew to 44mnt in 2021 from 28mnt in 2010.[5]

11.2.2 Fine Chemicals & New Materials: Growth Drivers for Japan's Photoresist Industry and China's Mixed Crystal Industry

11.2.2.1 Factors that Served as a Catalyst to the Rise of Japan's Photoresist Materials Industry and Helped the Country Maintain Its Leading Position

The semiconductor materials industry has a wide range of products, high technological barriers, and complex manufacturing techniques. Furthermore, downstream clients require a lengthy period to test and verify the products. In our opinion, R&D and industrialization of semiconductor materials are challenging, and should be further strengthened to ensure the stability and safety of China's industry chains. Semiconductor-related photoresists are one of the high-end fine chemicals and new materials. In our opinion, Japan continues to be one of the global leaders in this area, although its overall semiconductor industry chain is declining.

We note two types of changes in the global competitiveness of Japan's semiconductor material segment. First, some materials and related formulas continue to be upgraded, driven by technological iteration in downstream sectors. For example, Japan has been a leader in the global semiconductor-related photoresist segment, and continues to strengthen its competitive advantages. It captured growth opportunities amid transformation of the technological roadmap in the early twenty-first century and continued to optimize its photoresist products as technologies of its downstream clients advanced. Second, the continuous upgrading of semiconductor-related technologies poses higher requirements on the performance and purity of some chemical materials, including electronic wet chemicals, electronic special gases, polishing materials, and large-size silicon chips. Japan maintains a large global market share in these chemical material segments on the back of advantages accumulated in the past. However, its advantages in these segments are weaker than in the global photoresist market. In the following paragraphs, we mainly highlight the milestones of Japan's photoresist industry, which we expect will inspire China's high-end fine chemicals & new materials industry.

1960s–1980s: Japan overtook advanced countries on the back of the VLSI research project. Photolithography technology originated in Europe and the US

[4] Ethane is one of the raw materials for preparing ethylene.

[5] Source: CNPC Economics & Technology Research Institute.

in the 1950s. In the early 1960s, US companies were relatively relaxed about the transfer of technologies (TOT). As such, Japanese semiconductor materials companies acquired advanced technologies from their US peers via TOT and made some progress.

In 1968, Tokyo Ohka Kotyo Co., Ltd. (TOK) brought Japan's first cyclized rubber-based photoresist to the market. Later, the Japanese government encouraged related companies to work together on the R&D of core technologies, with the aim of accelerating the development of the country's semiconductor industry. In 1976, the Japanese government, Fujitsu, Hitachi, NEC, Mitsubishi Electric, and Toshiba jointly launched a VLSI research project,[6] investing JPY70bn in building a laboratory while studying basic semiconductor-related technologies. The project set up six laboratories to develop key semiconductor materials, equipment, and production technologies. Specifically, three laboratories were responsible for semiconductor equipment R&D, while the other three were used for the development of semiconductor materials, photolithography technologies, and packaging and testing technologies.

With four years of R&D and cooperation, the VLSI obtained more than 1,000 patents and made many technological breakthroughs. The successful development of the key equipment for semiconductor processing, a lithography device using model reduction steppers, is remarkable. Its R&D of the supporting photoresists also accelerated Japanese photoresist manufacturers' technological upgrading. In 1979, Japan's first CIF photoresist product made by JSR Corporation entered the market. In 1981, TOK's first factory specializing in the production of semiconductor-related photoresists started operating. The 1980s was a period of rapid growth for Japan's semiconductor industry. During this period, Japan grew into a leader in the global semiconductor industry. Benefiting from the robust demand in the downstream semiconductor industry, orders for photoresists made in Japan increased rapidly,[7] thus enabling Japanese photoresist companies that had achieved technological breakthroughs to secure a place in the global photoresist market then dominated by US companies.

1990s–2000s: Technological innovation and advanced equipment made Japan a leader in the global photoresist industry. From the 1990s to the beginning of the twenty-first century, Japan's photoresist industry developed by leaps and bounds on the back of photoresist-related technological transformation, and the production of advanced supporting equipment. During this period, the industry switched to krypton fluoride (KrF) photoresist technology from g-line and i-line photoresists. Although the US company IBM invented KrF photoresists as early as the 1980s, it did not put the product into large-scale commercialization due to the backward process technologies at that time. During this period, Japanese companies managed to narrow the gap with their US peers in the field of KrF photoresists via technological R&D. In 1995, TOK successfully rolled out its own KrF photoresist,

[6] DONG Shuli, and SONG Zhenhua. "Experience and Enlightenment of VLSI Projects in Japan and High-tech and Industrialization" *High Technology & Commercialization* 7(2013):6.

[7] YU Fei. "Industrial Development Analysis of Japanese Semiconductor." *Application of IC* 34.1(2017):6.

breaking IBM's monopoly in the KrF photoresist market. In terms of supporting lithography devices, Japan outperformed the US by output in 1985. In 1995, Nikon Corporation launched NSR-S201A, the world's first KrF lithography system that can be commercialized, overtaking its US peers. At this stage, Japanese companies surpassed US companies in the global lithography device market, and further eclipsed the original European and US leaders in the photoresist market on the back of their advanced lithography device-related technologies. At the end of the 1990s, Japanese photoresist manufacturers set up factories overseas, increasing their service coverage around the world. In 1997, TOK built Japan's first overseas photoresist manufacturing facility in Oregon in the US.

2000s–present: Japan maintains a leading position in the global photoresist industry on the back of technology roadmap transformation, as well as R&D and upgrading of supporting technologies. In the twentieth century, Japan narrowed the gap with technologically advanced countries in the fields of i-line, g-line, and KrF photoresists by increasing R&D investment, introducing cutting-edge technologies, and developing supporting facilities. In the twenty-first century, Japan joined the ranks of leaders in the global photoresist industry as it captured growth opportunities amid the technology roadmap transformation and stepped up efforts to upgrade supporting lithography devices. It maintains a leading position at present. At the turn of the twenty-first century, the global semiconductor industry shifted to ArF photoresists from KrF technology. JSR officially started development of the ArF photoresist-based, 130 nm process technology-driven semiconductor in 2000 based on its experience in the photoresist industry. As a result of its efforts, the Japanese company became a leader in the global ArF photoresist segment.[8] As ArF lithography technology is applicable to 7–130 nm processes, JSR and TOK continued to cooperate with downstream companies such as ASML in the R&D of lithography devices, and increased efforts to upgrade their products to adapt to changing technologies. As a result, Japanese companies strengthened their first-mover advantages in the field of ArF photoresists. In 2019, the new-generation EUV photoresist-related technology was poised to enter industrialization. On the back of their close ties with ASML and other lithography device manufacturers, as well as their forward-looking research, Japan again took the lead in industrializing EUV photoresists, enhancing its competitive advantages.

11.2.2.2 Factors Driving the Growth of China's Mixed Crystal Industry

The liquid crystal industry is technology-intensive, and the quality of materials directly affects the performance of panels. Manufacturing liquid crystal materials involves several processes, including preparing liquid crystal intermediates from basic chemical raw materials, synthesizing liquid crystal monomers (LCMs) from intermediates, upgrading to electronic LCMs via purification (removal of impurities,

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[8] Sanders, Daniel P. "Advances in patterning materials for 193 nm immersion lithography." *Chemical reviews* 110.1 (2010): 321-360.

moisture, ions, etc.), and mixing LCMs in the right proportions. The production of mixed crystal requires dozens of steps of synthesis, purification, and mixing of multiple monomers. Therefore, we think the mixed crystal industry is technology-intensive. The cost of liquid crystal materials generally accounts for 3–4% of the total cost of panels, and the quality of these materials directly affects the response speed, brightness, viewing angle, and other indicators of the display. Due to the importance of liquid crystal materials, downstream panel manufacturers' certification of mixed crystal material suppliers is strict and the certification cycle is long.

The improvement of material technology and the accelerated transfer of panel capacity to the Chinese mainland are driving the growth of the domestic mixed crystal industry. Based on technological strengths in the field of twisted nematic (TN) and super twisted nematic (STN) liquid crystal materials, domestic mixed crystal material companies expanded into the TFT business after 2000. In 2007, Yongsheng Huaqing (later acquired by Chengzhi) managed to produce TFT material in small batches in 2007. In 2010, Hecheng Display (later acquired by PhiChem) successfully developed the "indene ring" structure based on its cooperation with Daxin, a specialty chemical materials manufacturer in the Taiwan region of China. In 2011, BaYi Space started comprehensive R&D of TFT mixed crystal. With the improvement of TFT mixed crystal technology and product quality, domestic mixed crystal material manufacturers passed the tests of downstream customers and entered the supply chains of domestic LCD panel manufacturers by providing TFT mixed crystal material. PhiChem, BaYi Space, and Chengzhi were three leaders in the domestic mixed crystal market. By 2015, the localization rate of TFT material approached 15%. After 2015, the transfer of global LCD panel production capacity to the Chinese mainland accelerated, and domestic LCD panel manufacturers replaced all imported TFT mixed crystal raw materials with domestic products. As a result, the localization rate of mixed crystal increased rapidly.

11.3 Outlook for China's Chemicals Industry Chain

Countries around the world have been paying more attention to industry chain and supply chain security due to the rise of deglobalization and the impact of COVID-19 resurgence on global supply chains. As one of the pillar industries of the national economy, the petrochemicals and chemicals industry is critical to the security and stability of China's supply chain due to its characteristics of "large trading volume, long industry chain, diverse product categories, and wide downstream applications".

Outlook for China's chemicals industry: **(1) Commodity chemicals:** We review the industrial transfer in the global ethylene market, and note that demand and costs have been the main drivers of the industrial transfer after the production technology of commodity chemicals matured. We believe that China will remain competitive in key commodity chemical segments given the strong demand and macroeconomic growth in China, leading companies' capex growth for core capacity expansion and penetration into downstream sectors with high added value, rise in natural gas prices, and unstable supply in important chemicals production bases such as Europe. In the fields of polyolefin elastomers (POE) and EVA, which have high import dependency, we expect the self-sufficiency ratio in China to increase as related domestic production capacity expands. In our opinion, some commodity chemical production capacity will likely face transfer pressure due to the rise of deglobalization, increasing labor costs, and the green transformation of industries.

(2) Fine chemicals & new materials: The localization rate of high-end fine chemicals and new materials is relatively low at present. We expect the development of downstream sectors and related policy support to drive the growth of this industry in China. However, this industry has high technological barriers, and there is still a gap between China and advanced countries in terms of technological strengths as well as speed of technological iteration. These factors will likely slow China's pace of localization in the high-end fine chemicals & new materials industry. Given the frequent changes in related materials and formulas, driven by technological iteration in the downstream semiconductor sector, we think it may take a long time for China to localize semiconductor photoresists. With the iteration of semiconductor technologies, requirements for the performance of electronic wet chemicals, electronic special gases, polishing materials, and large-size silicon wafers will likely increase, and the localization progress in these chemical materials segments will likely accelerate in the medium and long term.

11.3.1 Commodity Chemicals: Competitiveness Remains in Key Segments; Pressure from Industrial Transfer Emerges in Some Segments

China maintains competitiveness in the global commodity chemicals industry due to increasing demand and improving supporting facilities. In our opinion, the sustained growth of China's macroeconomy will likely continue to boost demand for chemical products. In addition, China accounts for a high proportion of the global market by production capacity of major commodity chemicals. At present, prices of natural gas and electricity have soared in Europe, one of the world's main chemical manufacturing bases, due to **geopolitical factors**. Supply pressure has also emerged in the region. Therefore, we expect China to see cost advantages in key commodity chemical segments. In July 2022, BASF decided to accelerate the construction of a project in Zhanjiang, Guangdong province. Other global chemical giants also invested on a large scale in China, reflecting their optimism about the market prospects and competitiveness of commodity chemical projects in China.

Leading companies with strong competitiveness will maintain large capex, and China's global market share of commodity chemicals will likely continue to increase. Data from CEFIC shows that capex of Chinese chemical enterprises in 2020 was EUR92.2bn, implying a CAGR of 5.5% in 2010–2020. The large scale and high growth rate of capex continued to fuel the expansion of China's market share of chemicals. Based on our survey of some petrochemicals and chemicals providers, we expect Rongsheng Petrochemical, Hengli Petrochemical, and Wanhua Chemical to each maintain capex of more than Rmb100bn over 2022–2025, and capex of Tongkun Group, Xinfengming Group, and Hualu Hengsheng to each exceed Rmb20bn. Leading companies will mainly fund capacity expansion for existing products, industry chain extension, and development of new materials and high-end materials businesses. We are upbeat on the continuous expansion of chemical production capacity in China.

Some segments will likely face industrial transfer-related pressure due to higher labor costs and green transformation, in our view. **(1) Labor-intensive industries:** As labor costs rise in China, labor-intensive industries such as textiles will likely see industry chain transfer. For example, Jiangsu Guotai International is building processing plants in Southeast Asian countries, including Vietnam. In our opinion, demand in China will also decline against the backdrop of industrial transfer, thus putting pressure on the growth of the chemical materials industry in China. **(2) Industries with high energy consumption:** The implementation of low-carbon policies in China makes it difficult for projects with high energy consumption to be approved. Therefore, we think that companies in the oil refining, urea, yellow phosphorus, and industrial silicon segments may increase investment in overseas projects.

11.3.2 Fine Chemicals & New Materials: Prospects of Downstream Sectors Decide Material Demand; Multiple Factors Affect the Localization of High-End Materials

The trading volume of high-end fine chemicals and new materials in the market is relatively low. However, these materials have high technical barriers, and their quality, reliability, and stability greatly impact the performance of downstream products. The cost of these materials as a proportion of downstream clients' total costs is low. If there are no restrictions on the purchase of raw materials, downstream clients tend to maintain business relationships with existing suppliers. This means that high-end fine chemicals and new materials have strong customer stickiness. However, some countries have increased restrictions on the export of certain materials considering the growing need for ensuring supply chain security and improving supply chain resilience. Although the technological gap between China and advanced countries is sizable and localization is facing major challenges, we are optimistic about new growth opportunities for the domestic high-end fine chemicals & new materials industry amid policy tailwinds and growing demand for domestic products from downstream sectors in China.

We believe the rapid growth of downstream demand and policy tailwinds in China will drive the growth of domestic products in some fields with relatively

low localization rates. At present, the display panel and semiconductor industries are expanding in China. In terms of LCD panel capacity, China is a leading global producer. In terms of OLED panel capacity, Chinese companies' global market share is increasing rapidly. The size and sales value of China's integrated circuit market and the market share of Chinese enterprises in the global wafer foundry market are also ramping up. In addition, China has introduced several policies and offered capital support to spur the development of the domestic semiconductor industry. Given that demand from the downstream semiconductor and display panel manufacturing industries is also increasing, we expect the localization of high-end fine chemicals and new materials to continue.

High technical barriers and downstream technological iterations will likely affect China's progress in localizing high-end fine chemicals and new materials. Generally speaking, it is relatively challenging for Chinese companies to develop and industrialize fine chemical and new material products given the high technical barriers at present. However, the progress in technological iterations varies among downstream industries, and difficulties in material industrialization for different downstream industries are not comparable, in our view. If the materials industry and production technology are constantly changing along with the technological iteration of downstream industries, we believe that material localization will be more difficult. However, if downstream demand for materials and production technologies is relatively stable, we expect the localization to be smoother as domestic companies increase efforts to improve technologies and techniques. In the following paragraphs, we mainly analyze the prospects of semiconductor materials and some panel materials in China.

Localization of photoresists still requires a lengthy period due to the continuous changes in materials and formulations caused by downstream technology iteration. Driven by Moore's Law, the chip manufacturing industry continues to upgrade to more advanced techniques, and the requirements for key lithography technologies continue to improve. For example, by the wavelength of the exposure, lithography technology has evolved from g-line, i-line, KrF, and ArF to the most advanced extreme ultraviolet light. As photoresists are the core material required by lithography technology, the formulas for photoresist materials are constantly changing while the product purity keeps improving. The materials have shifted from the phenolic resin-diazonaquinone system used in g- and i-lines, and poly (p-hydroxystyrene) and derivatives for KrF lithography to poly (methacrylate) for ArF technology. At present, the world's most advanced EUV lithography technology uses 13.5 nm extreme ultraviolet light source, and photoresist materials for the technology have been upgraded to molecular glass and metal oxide, among others. As lithography technology is upgraded, the technological gap between China's photoresist companies and their overseas counterparts has widened. At present, g-line, i-line, and KrF lithography technologies are still the mainstream technology roadmap in China's photoresist industry, and ArF and EUV photoresists are mostly imported. Given the large technological gap, as well as overseas countries' regulations on the purchase of supporting advanced equipment and the high cost of trial and error for the application of domestic photoresists, we believe that the time required for the localization of high-end photoresists such as ArF and EUV will be long.

Localization of semiconductor materials will likely accelerate in the medium to long term, although requirements on performance of semiconductor materials continue to increase amid downstream technological iteration. The semiconductor manufacturing industry has stringent requirements for the purity of electronic wet chemicals, electronic special gases, and polishing materials; the content of metal impurities; the number of particles; and the consistency of particle size and quality. The continuous upgrading of semiconductor manufacturing processes has led to stricter requirements for the purity of semiconductor materials. For example, the continuous reduction of the semiconductor processes has resulted in lower tolerance for defect density and size of silicon wafers. As a result, wafer providers must control defects of monocrystalline silicon, the surface roughness of the silicon wafer, and the content of metal impurities. To date, domestic companies have made breakthroughs in the fields of electronic wet chemicals, electronic special gas, polishing pad and polishing fluid, and 300 mm silicon wafer. On the back of technological accumulation and experience in product purification and mixing accuracy, we expect the progress in localization of these materials to accelerate in the medium and long term.

The new energy material industry in China may face risks related to the rise of deglobalization in the industry chain. Data from www. guangfu.bjx.com and PV Infolink shows that the top 10 global leaders by PV module shipments in 2021 include eight domestic companies such as Longi Green Energy and Jinko Solar. Module shipments of these eight Chinese companies equaled approximately 90% of the global installed PV capacity in 2021. According to SNE, Chinese companies Contemporary Amperex Technology and BYD were among the top five global leaders by automotive battery shipments. Total automotive battery shipments of the two companies approached 132.7GWh, accounting for about 50% of the global power battery shipments. The development of Chinese midstream companies also facilitates the localization of new energy materials. In addition to conductive carbon black and POE, most new energy materials have been localized. However, some key economies are calling for increasing the use of their own products in the new energy industry chain. For example, the Inflation Reduction Act was passed in the US to protect their own new energy industry chain, and Chinese LiB-related companies may see risks related to industrial transfer.

11.4 Thoughts and Implications

11.4.1 Commodity Chemicals

11.4.1.1 Address Green and Sustainable Development and Cultivate Companies with Global Competitiveness in Segments with Strong Advantages

Strengthen green and sustainable development. Commodity chemicals have a longer history of development than other chemicals, and related technologies are relatively mature. As a result, participants in this segment may face global competition. China has established competitive advantages in terms of the market, costs, and security and stability of supply. We believe that China will continue to strengthen its advantages in MDI and other commodity chemical segments in the coming years. In our opinion, relevant domestic companies should enhance their long-term competitiveness by diving into green and sustainable R&D projects, including diversification of raw materials, carbon dioxide utilization, and atom utilization in the process.

Cultivate companies with global competitiveness. China has the world's largest chemicals market. Among the top 50 chemicals manufacturers in the world in 2022, however, only nine were Chinese companies, namely Sinopec, Formosa Plastics, PetroChina, Hengli Petrochemical, Syngenta Group, Wanhua Chemical, Rongsheng Petrochemical, Tongkun Group, and Hengyi Petrochemical. In our opinion, China's chemicals industry has its weaknesses but also growth opportunities. Given the country's large chemicals market, we expect a number of domestic companies to grow into global leaders, thus helping China enhance competitive advantages in the global chemicals industry in the long term.

11.4.1.2 Industry Chains Facing Transfer Pressure Should Accelerate Overseas Expansion

For the tire industry and other industries facing overseas tariff barriers, we suggest building factories overseas. Since 2015, the US has imposed an anti-dumping duty of 14.35–87.99% and countervailing duty of 20.73–116.33% on the invoice value of tires (for passenger vehicles) exported from China.[9] The tariff barriers are relatively high. To weaken the impact of high tariff barriers, some big-name tire companies have stepped up efforts to expand capacity, mainly in Thailand, Vietnam, and other Southeast Asian countries, and the main category of their exports is semi-steel tire. However, the tariff barriers to tires from Southeast Asia have increased in recent years. As of May 2021, the total tax rate (combination of anti-dumping duty and countervailing duty) was 14.62–21.09% for products from

[9] https://www.usitc.gov/publications/701_731/pub5158.pdf.

Thailand and 6.23–28.76% for products from Vietnam. We survey the geographical distribution of related Chinese companies' capacity expansion projects under construction, and believe that Europe, the Americas, and Africa will likely be the main focus of Chinese tire manufacturers.

Production capacity of the labor-intensive textile industry is moving to Southeast Asia, and Chinese raw material providers should mitigate risks related to decline in their market share via free trade agreements. There is an obvious trend of production capacity transfer in some industry chains, including the textiles & apparel industry chain, and Southeast Asia has strong competitive advantages in this round of industrial transfer. In our opinion, China should sign free trade agreements with Southeast Asian countries, thus strengthening industrial division and cooperation among regions. We expect China's chemicals industry to maintain competitive advantages by providing capital-intensive industrial intermediates and processing downstream products overseas.

Implement differentiated policies to support the development of core fields in energy-intensive industries. China's efforts toward reaching peak carbon emissions and achieving carbon neutrality have led to higher requirements for the development of energy-intensive industries. China's urea and refining industries: We propose that related companies expand overseas capacity in a sustainable manner and transform into multinational companies with global competitiveness. Anode materials and industrial silicon industries: Anode materials and industrial silicon are necessary for the development of downstream new energy industries.

11.4.2 Fine Chemicals & New Materials

11.4.2.1 Localization Rate of High-End Materials is Relatively Low; Chinese Companies Should Step up Efforts to Tackle Technical Problems

Tackle technical problems in the industry chain. To accelerate the development of its semiconductor industry, Japan launched the VLSI research project, investing JPY70bn in related technology R&D and encouraging companies and research institutes to share information. Due to these efforts, Japan's semiconductor industry has significantly improved its technologies. At present, there is a large gap between China and overseas countries in semiconductor material-related technologies. We believe China can learn from Japan and focus on tackling technical problems in the industry chain. First, domestic companies can select one process and focus on making breakthroughs in equipment, materials, and other related technologies. This can also lay a solid foundation for companies' subsequent technological iteration. Second, major companies along the industry chain should work together. For example, in the field of materials, the key R&D tasks were mostly distributed to small- and medium-sized enterprises (SMEs) in the past. However, SMEs' own profitability was weak, which affected their R&D investment. At this critical moment, we expect leading chemicals manufacturers in China to shoulder greater responsibilities. Third, in some sectors that involve multiple categories of materials, we suggest creating sector leaders via M&A. For example, there are hundreds of product categories in the fields of electronic wet chemicals and electronic specialty gases, and many companies in the two sectors have one or several competitive products. M&A can help create sector leaders with a wide range of product coverage. We think this is not only conducive to serving downstream application providers, but also helps create generic technologies, thus supporting the development of a wider range of product categories.

Encourage downstream customers to test and use domestic materials. For example, downstream companies are not motivated to use domestic photoresist materials as the quality of photoresists is crucial to the lithography process and trial and error costs in the downstream are high. As a result, we propose that China enhance the synergies between upstream and downstream industries by building a trial and error compensation mechanism, thus increasing subsidies for material purchasers and encouraging companies to work together in a research project. In addition, we suggest that China build a public test platform. For example, in the photoresist segment, the unit selling price of an EUV lithography machine is around US$150 mn. The cost of a machine is high for a single company and purchasing the machine is restricted by some overseas countries. A public platform may significantly reduce companies' R&D costs and avoid wasting of resources.

Strengthen companies' R&D. There are two ways for companies to enhance their R&D. First, create a culture of innovation. Management of companies should leave room for innovation and create a culture that supports employees' innovative activities. Second, strengthen incentives for innovation and skilled workers. Chemicals companies should develop an efficient employee incentive and promotion system, continue to optimize organizational structure, enhance employees' sense of belonging and pride, and reduce the loss of highly skilled personnel. Related government departments could also help Chinese chemicals manufacturers establish long-term and sustainable innovation capabilities.

Set up overseas R&D centers and strengthen the exchange of advanced technologies. Downstream industries in overseas markets have a long history of development, advanced technologies, and relatively complete employee education mechanisms. By building overseas R&D centers, Chinese chemicals companies may see three benefits. First, they can communicate with downstream customers and ascertain the actual demand for relevant materials. Second, domestic companies can attract skilled workers from local industries to help them improve R&D capabilities. Third, these chemicals manufacturers can cooperate with renowned universities, colleges, and companies in overseas countries in R&D projects.

11.4.2.2 Chinese Companies Are Competitive in the New Energy Materials Industry; We Expect Them to Accelerate the Development of New Technologies

Accelerating the development of new technologies and enhancing competitiveness to maintain a leading position. We review the announcements of a wide range of companies and note that in the field of LiB, Chinese battery company Contemporary Amperex Technology (CATL) has launched the Qilin battery, which has a record-breaking volume utilization efficiency of 72% and an energy density of up to 255Wh/kg. Meanwhile, the energy density of the E603P8S battery module from LG, the global leader, is only 226Wh/kg. We believe that China is a global leader in terms of battery technology due to its ternary and lithium-ion battery technology frameworks. Looking ahead, we believe that the energy density of solid-state batteries will likely exceed 400Wh/kg. As a result, there remains substantial room for technological upgrading by Chinese companies. In our opinion, related government departments could encourage companies to research and develop new energy materials and new technologies by launching advanced material projects and providing subsidies for related industries. New technological breakthroughs can also help China maintain a leading position in the global new energy materials industry.

Domestic companies with competitive advantages should proactively build factories in developed countries to meet the localization needs of industry chains in major countries and regions. In the future, the US and some other regions will likely enhance the competitive advantages of their local industry chains. The global new energy materials industry will likely face the risk of market protection by developed economies. We suggest related Chinese companies take the initiative to accelerate the construction of overseas factories and tap into overseas demand.

Chapter 12
Create Conditions for High-End Equipment Manufacturers' Technological Accumulation

Abstract Equipment manufacturing is the central part of industrial engineering. In the current international environment, we believe China is at risk of facing bottlenecks on key technologies. We think it is prudent for China to elevate the level of the domestic equipment manufacturing industry, segments of which generally have large scale owing to sizable market demand, a sufficient labor force including engineers, and advanced infrastructure. However, the competitiveness of these segments has diverged: China's new energy equipment and high-speed railway (HSR) industries have secured dominant positions in the global market, while its machine tools and large aircraft industries lag that of other countries. We believe assessing the underlying cause of the imbalance is important to investors as it helps clarify the pattern of development and policy orientation of the equipment manufacturing industry. In this chapter, we analyze the factors boosting the equipment manufacturing industry's development based on substantial evidence and theories, and we proffer policy suggestions.

Industry overview: Limitations in highly sophisticated equipment and core components apparent. Horizontally, China's equipment manufacturing industry has a large output value: Real estate infrastructure equipment, metalware, flexible units, and energy equipment represent a relatively high proportion of global supply. However, we see an insufficient supply of high-grade, high-precision, and advanced products in China. Vertically, domestic suppliers generally have weak capabilities in core components despite the strong deliverability of complete machines, in our view. Most of the domestically made components are at the lower ends of the smile curves (The smile curve represents the seven-step manufacturing value chain, demonstrating that value across a production cycle is largely derived from early stage R&D, design, and post production activities (i.e., distribution, sales, and after-market service activities.) along the industry chain. We expect the added value to increase in the future.

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Industry chain changes: Complete machine manufacturing being relocated from developed regions to China. Looking at the changes in representative industries over the years, we note that market demand has become a prerequisite for industrial layout, while supply capacity and policies affect the distribution pattern of specific industries or segments. China has received a large number of industrial transfers from developed countries as the domestic market expands; however, most of these transfers are complete machines. Core components are not available through industrial transfer and require independent R&D.

To chase the technological frontier, China must accumulate manufacturing techniques essential for the equipment manufacturing industry's development, in our view. China's success in this regard is dependent upon: (1) The initial technological gap; (2) characteristics of downstream demand; (3) core supporting resources and competitive pressure from foreign capital; and (4) relevant policies, which could bring changes to the former three factors and create opportunities for companies to accumulate technologies. These factors influence the development paths and outcomes of different industries.

Policies should be formulated based on actual conditions of industries. Looking ahead, with the restructuring of the global industrial value chain, we believe policies for industries with different strategic positions will vary based on industrial relocation. For weak industries, reducing the costs borne by downstream companies replacing overseas equipment with domestically made products (hereinafter referred to as "trial-and-error costs") and strengthening supply protection could help enhance competitiveness, in our opinion. For robust industries, we think it is necessary to strengthen their technological leadership and ensure companies' global expansion.

Keyword Project-based industries · Product-based industries · Infrastructure construction equipment

12.1 Overview of Equipment Manufacturing Industry

The equipment manufacturing industry is an umbrella term for various manufacturing industries that provide equipment for simple production and expanded reproduction in all branches of the national economy.[1] Being at the core of industrial engineering, the equipment manufacturing industry plays an indispensable role in buttressing manufacturing processes from infrastructure construction to product fabrication. It usually has a long industrial chain, and its production relies heavily on technologies and capital.

China's manufacturing industry accounted for about 30% of the world's value-added output in 2021. Increasingly, China faces challenging externalities as it transitions from a manufacturer of quantity to one of quality. Some strategic industries

[1] *Modern Management Textbook.* Enterprise management publishing house, (2006)

(e.g., machine tools and semiconductor equipment) are confronted with major technology bottlenecks. Certain downstream sectors may be impeded from production once relevant equipment or core devices are not available through trade. Therefore, boosting the development of the equipment manufacturing industry is key to economic growth, in our view.

12.1.1 Comparison of Representative Equipment Manufacturing Industries in China, the US, Japan, and Europe

Our analysis shows that in 2022, the gross output of representative categories in the global equipment manufacturing industry totaled nearly Rmb9trn, including about Rmb3trn in China, approximately Rmb2trn each in the US and Europe, and nearly Rmb1trn in Japan.

China's real estate infrastructure equipment, metalware, shipbuilding, and energy equipment-related industries represent a large proportion of the world's total output, while high-precision equipment only accounts for a small proportion. Based on its exceptionally large volume of real estate infrastructure construction and foreign trade, China's real estate infrastructure equipment, metal products, and shipbuilding industries have high global output value. In 2022, the output of China's major general-purpose equipment accounted for one-third of the world's total thanks to a sizable manufacturing industry. As a powerhouse both exploiting traditional energy and transitioning to renewable energy, China has secured a world-leading position as measured by the industry scale of both industries. However, China is a latecomer in high-precision industries[2] such as the semiconductor equipment and large aircraft industries, lagging behind overseas counterparts (led by the US) and representing a relatively small proportion of global output value (Fig. 12.1).

12.1.2 Supply and Demand Conditions of China's Equipment Manufacturing Industry in the Global Market

We note that most industries maintain coordinated supply and demand, as well as a relative balance between imports and exports. Specifically, China's photovoltaic (PV) equipment and lithium battery (LiB) equipment industries account for a relatively high share of the global market. We think the two industries may be key fields wherein other countries promote reshaping of the industrial chain moving forward.

[2] Beijing Municipal Bureau of Statistics and Beijing Municipal Bureau of Economy and Information Technology. Category of advanced industrial activities in Beijing. 2017. High-precision industries refer to technology-intensive industries with high output benefits and yield efficiency, and low resource consumption.

Categories	Products	China	USA	Japan	Europe	World
Real estate infrastructure equipment	Railroad equipment	300	300	42	360	1,140
	Construction machinery	420	260	210	95	1,000
	Agricultural machinery	300	250	60	300	1,000
	Total	**1,020**	**810**	**312**	**755**	**3,140**
Metal products	Hardware	525	50	30	80	700
	Shipping container	95	0	0	0	100
	Total	**620**	**50**	**30**	**80**	**800**
Transportation	Shipbuilding	450	180	100	100	1,100
	Large aircraft	100	600	25	500	1,300
	Total	**550**	**780**	**125**	**600**	**2,400**
General equipment	Lathe	111	37	104	74	370
	Robotics	41	14	84	40	180
	Laser equipment	84	35	9	32	160
	Injection molding machine	40	16	8	16	80
	Total	**276**	**102**	**205**	**163**	**790**
Specialized equipment	Coal equipment	140	20	0	10	300
	Lithium electric equipment	100	3	20	3	126
	Photovoltaic equipment	89	9	3	11	110
	Wind power equipment	160	36	1	65	300
	Nuclear power equipment	50	10	10	26	100
	Semiconductor equipment	20	280	210	190	700
	3D printing	25	35	10	20	100
	Satellite internet	5	27	1	15	50
	Total	**589**	**419**	**255**	**339**	**1,786**
	Sum of total	**3,055**	**2,162**	**927**	**1,937**	**8,916**

Categories	Products	China	USA	Japan	Europe
Real estate infrastructure equipment	Railroad equipment	26%	26%	4%	32%
	Construction machinery	42%	26%	21%	10%
	Agricultural machinery	30%	25%	6%	30%
	Total	**32%**	**26%**	**10%**	**24%**
Metal products	Hardware	75%	7%	4%	11%
	Shipping container	95%	0%	0%	0%
	Total	**78%**	**6%**	**4%**	**10%**
Transportation	Shipbuilding	41%	16%	9%	9%
	Large aircraft	8%	46%	2%	38%
	Total	**23%**	**33%**	**5%**	**25%**
General equipment	Lathe	30%	10%	28%	20%
	Robotics	23%	8%	47%	22%
	Laser equipment	52%	22%	6%	20%
	Injection molding machine	50%	20%	10%	20%
	Total	**35%**	**13%**	**26%**	**21%**
Specialized equipment	Coal equipment	47%	7%	0%	3%
	Lithium electric equipment	79%	2%	16%	2%
	Photovoltaic equipment	81%	8%	2%	10%
	Wind power equipment	53%	12%	0%	22%
	Nuclear power equipment	50%	10%	10%	26%
	Semiconductor equipment	3%	40%	30%	27%
	3D printing	25%	35%	10%	20%
	Satellite internet	10%	54%	2%	30%
	Total	**33%**	**23%**	**14%**	**19%**
	Sum of total	**34%**	**24%**	**10%**	**22%**

Fig. 12.1 Representative equipment manufacturing industries in the US, China, Japan, and Europe. *Note* Data in the table on the left refers to 2022 output value (Rmb bn), while the table on the right refers to the proportion of global output value, with countries or regions with the highest proportions marked in red. *Source* China Construction Machinery Association, China Machine Tool & Tool Builders' Association, China Photovoltaic Industry Association, corporate filings and official websites of CIMC, GreatStar, and China State Railway Group; CICC Research

In the machine tools, industrial robots, and large aircraft industries, China's supply as a percentage of the world's total is lower than its share of global demand, mainly due to certain unsolved technological barriers. We expect China to focus on the development of these industries in the future. In the tools and container industries, China's percentage of global supply is notably higher than its share of global demand, demonstrating China's advantages in the supply chain and manufacturing costs. Although containers and handwork tools do not have high technological barriers to entry, they need a large amount of steel for manufacturing, requiring a large-scale metal processing industry. Other developing countries have yet to develop mature supply chains for such manufacturing at this stage. In addition, due to the high transportation cost for containers, countries with large trading volumes can reduce additional sea freight costs while building them. We think China needs to further strengthen or maintain its advantages in the industrial chain, keep a relatively leading status in technology development, and avoid trade restrictions by diversifying its industry chains (Fig. 12.2).

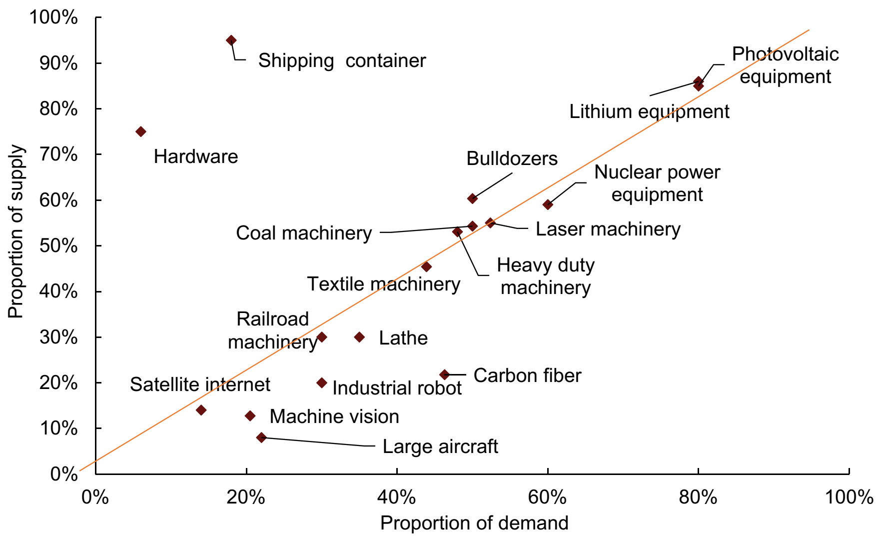

Fig. 12.2 Global supply and demand patterns of various industries. *Note* Horizontal axis refers to China's demand as a percentage of global demand, while vertical axis represents China's supply (including that from foreign companies) as a percentage of global supply; data as of 2022. *Source* China Construction Machinery Association, China Machine Tool & Tool Builders' Association, China Photovoltaic Industry Association; corporate filings and official websites of CIMC, GreatStar, and China State Railway Group; CICC Research

12.1.3 Localization Rate of Segments in China's Equipment Manufacturing Industry

Vertically, China's equipment manufacturing industry focuses on complete machines rather than supporting products, and is experiencing an insufficient supply of mid-range and high-end offerings.

Focus on complete machines rather than supporting products. Compared with components, complete machines have higher output value, and their development is based on capital rather than technologies. As such, domestic manufacturers tend to first make breakthroughs in complete machines. In China, most industries pay attention to the R&D of complete machines in the early stages of development, but the production of supporting core parts is relatively ignored. For example, the proportion of domestically made products in the construction machinery, machine tools, and other industries is high, while the self-sufficiency rate of core components is low.

Supply of mid-range and high-end products insufficient. China has gradually achieved breakthroughs for some components with relatively low technical difficulties (i.e., light sources, conventional lenses, and cameras) in the machine vision segment. It takes time for breakthroughs to be made in some high-end parts, as well as for the new technologies to be adopted by clients. For instance, China has a low localization rate in the high-end product (e.g., large tow carbon fibers and smart cameras), laser equipment chip, and software industries.

12.2 Smile Curves of Equipment Manufacturing Industry and Changes in Industry Chains

The previous section addressed the overall development and global status of China's equipment manufacturing industry. In this chapter, we analyze the smile curves of three representative industries and review the evolution of their industry chains to identify the global position and growth drivers of China's equipment manufacturing industry. Among industries with strategic importance but relatively insufficient domestic supply, we select the large aircraft industry. We also choose the excavator and PV equipment industries among those with global competitiveness, large upside potential in overseas market expansion, and complete machines representing a high proportion of global output value.

From the smile curves of these industries, we observe that China's PV equipment industry boasts comprehensive advantages, while other industries have ample potential for expansion into high-value-added segments. Regarding changes in the value chain, companies in all industries have shown a process of migration from the US, Japan, and Europe to China. However, these companies mainly transfer segments of complete machines while keeping core components local. Most of China's equipment manufacturing industries see no pronounced pressure from relocation, in our opinion.

Looking ahead, we think policies should be adapted to industries with different strategic positions.

12.2.1 Large Aircraft Industry

12.2.2 Smile Curve: China Mainly Participates in Subcontract Manufacturing in Segments With Low Added Value

OEMs are at the core of the entire value chain and see higher added value on both ends. The equipment manufacturing segment has the largest scale and a core position in the value chain, despite also having the lowest gross margins (GM). In the large aircraft industry, original equipment manufacturers (OEMs) such as Boeing and Airbus outsource the R&D of subsystems to other companies and assemble equipment themselves. They set high barriers to entry for suppliers, further consolidating their leading positions in the industry chain. Segments' added value gradually increases from aviation equipment to each end of the value chain, with raw materials and maintenance segments reporting the highest GMs.

China is mainly responsible for subcontract manufacturing in the global aviation value chain and has limited exposure to high-value-added segments. Western Europe and the US are deeply involved throughout the entire aviation value chain and enjoy significant advantages in raw materials, airborne equipment, engines, and other technology-intensive segments. They keep production of these segments local, and only outsource some labor-intensive segments. Currently, China's aviation value chain mainly focuses on special-purpose aircraft. As for commercial aircraft, China mainly participates in the subcontract manufacturing of engine components (Aero Engine Corporation of China is the major manufacturer) and fuselages (Aviation Industry Corporation of China is the major producer). Domestic companies are less involved in technology-intensive segments due to overseas restrictions on subcontract manufacturing and the technological gap between China and other countries (Fig. 12.3).

12.2.2.1 Evolution of Value Chain: The US and Europe Have Secured Dominant Positions; China Shifting from Subcontract Manufacturing to Self-Built Value Chain

The US and Europe dominate core segments of the global value chain; East Asia increasing engagement in labor-intensive segments such as airframes and engine components. In the twentieth century, almost all manufacturing processes of large aircraft were completed in the US and Europe, with a small proportion of airframe components, engine parts, and maintenance services outsourced. In the

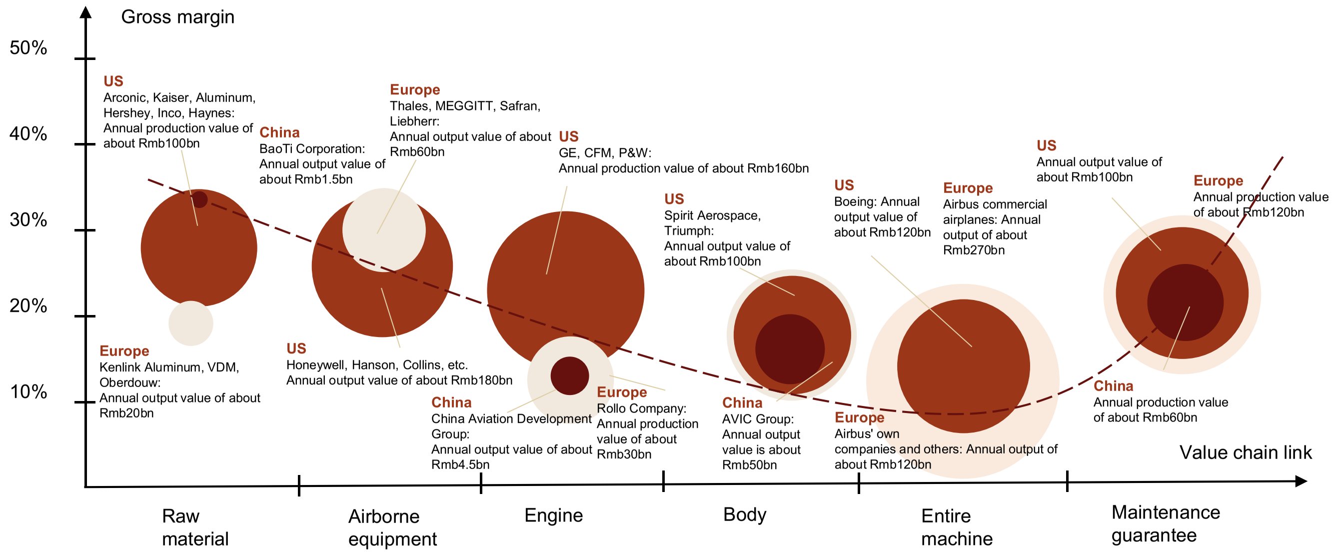

Fig. 12.3 Global landscape of large aircraft value chain. *Note* Bubble sizes indicate 2022 output value; we use 2021 GM data in this figure. *Source* LV Fei. *Analyzing the Path of China's Aviation Manufacturing Industry Upgrade Based on Global Value Chain. Journal: Practice in Foreign Economic Relations and Trade*. 2013 (5), Aero Dynamic Advisory, corporate filings, CICC Research

early twenty-first century, the previously outsourced segments in the aviation industry were shifted to East Asia: China, Japan, and South Korea became more involved in the global aviation industry chain. We estimate that the participation of the US and Europe in airframe structure and maintenance support segments gradually declined to 74% from 86% and to 74% from 85% in the early twenty-first century. However, the raw material, airborne equipment, and engine segments are still dominated by the US and European companies, with nearly 100% participation.

Demand: Traded domestic market share for technologies; commenced subcontract manufacturing. According to data disclosed by the Civil Aviation Administration of China, the number of transport aircraft increased to 4,054 at end-2021 from 661 in 2003. The rapidly expanding aviation market has supported technological exchanges of latecomers. Under the subcontract manufacturing model in this stage, Chinese companies mainly signed aircraft orders with overseas OEMs in exchange for subcontracted production orders of aircraft parts and components, thereby transferring part of the manufacturing process. During this period, production costs in China were higher than those in overseas markets, and "trading market for technologies" became an important way to integrate into the global value chain.

Supply: Technologies drove industrial expansion; cost and technological advantages attract subcontract orders. By the end of the 1980s, China produced certain airframe parts and continued to expand the production scale and coverage backed by its early experience in subcontracting. Entering the twenty-first century, as technology transfer boosted industry expansion, China and other latecomers gradually abandoned the "market-for-technology" subcontracting model. Over time, China established full-fledged industrial clusters in the fields of airframe structure and maintenance support. Airbus and Boeing also built assembly lines in Tianjin and Zhoushan. China's participation in complete aircraft and airframe structure increased further. Japan's and South Korea's participation in engines gradually increased thanks to the technological advantages of their high-temperature alloy and forging & casting companies in aircraft blades.

Policies: Embraced global value chain; domestic flagship enterprises forwarded core segments. From the 1980s to the early 2000s, China proposed exchanging the domestic market for subcontract manufacturing orders (i.e., the "three-step" strategy), expecting to complete the development of large aircraft with the help of advanced technologies from overseas manufacturers. At the end of the twentieth century, China held an approximate 8% share in the global airframe structure manufacturing commercial aviation market, as well as about 3% in engine parts manufacturing and about 5% in aircraft maintenance support. However, subcontracted production orders were stagnant, and relevant cooperative development in key manufacturing processes was rejected by major airlines in the early 2000s. China then started to develop its own large aircraft industry. With Commercial Aircraft Corporation of China (COMAC) as the flagship company, China integrated domestic and foreign suppliers and gave priority to domestic suppliers. In weak segments, China promoted cooperation between domestic and overseas manufacturers and eventually promoted the development of domestic industrial clusters (Fig. 12.4).

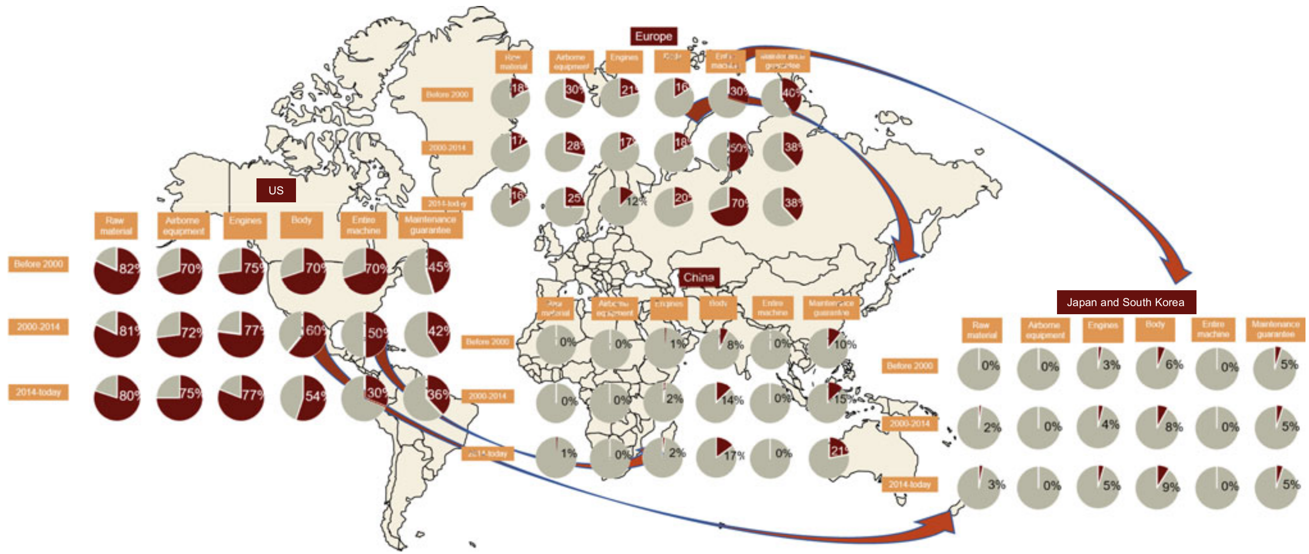

Fig. 12.4 Evolution of the global large aircraft value chain. *Note* Percentages refer to the proportion of China's output in the world's total. *Source* LV Fei. *Analyzing the Path of China's Aviation Manufacturing Industry Upgrade Based on Global Value Chain*. *Journal: Practice in Foreign Economic Relations and Trade*. 2013 (5), Aero Dynamic Advisory, CICC Research

12.2.3 *Excavator Industry*

12.2.3.1 Smile Curve: Leading Position in Equipment Application; Hydraulic Components and Engines to Improve

The excavator value chain mainly comprises components, complete equipment, and after-sales services. Excavator components mainly consist of components, engines, and hydraulic parts. Engines and hydraulic components are the most difficult to manufacture, while high-end hydraulic components and after-sales services generate the highest GMs.

China's original excavator equipment manufacturing has a high localization rate and boasts the world's largest output value. In the past two years, annual global sales volume of excavators stayed at about 600,000–800,000 units. China accounted for about 40% of global excavator output. The share of domestic brands in China's excavator market exceeded 70% in 2021. Sany's excavator sales volume reached nearly 100,000 units in 2020, overtaking Caterpillar as No.1 for the first time. Japan was second only to China, with an annual excavator output of nearly 200,000 units.

Japan, the US, and Europe dominated the high-end excavator parts market. Hengli Hydraulic led the oil cylinder market a step toward import substitution. However, a gap remains between its overseas position and that of Kawasaki (Japan). The latter and Rexroth (Germany) developed advanced technologies in pumps and valves. In the domestic small excavator market, Hengli managed to replace imported products and secured nearly 50% of market share, albeit with a relatively weak presence in the medium and large excavator markets. Excavator engines are mainly supplied by Cummins (the US) and Isuzu (Japan). Chinese OEMs rely on imports or supply from joint ventures — e.g., the Cummins manufacturing base in Guangxi, jointly built by Guangxi LiuGong Group and Cummins (Fig. 12.5).

12.2.3.2 Evolution of Value Chain: Transfer as Real Estate and Infrastructure Construction Peaks; Japan Remains the Largest Supplier of Core Components

The excavator industry chain developed rapidly in Japan, the US, and Europe before it migrated to China. Excavators originated in Europe and the US as they took the lead in industrialization. Due to the geographical environment, application habits, and product prices, loaders were more commonly used in Europe and the US during the early stages. In the 1950s and 1960s, hydraulic excavators gradually replaced mechanical excavators. In Japan, the development of the construction industry led to the widespread use of hydraulic excavators. Since the beginning of this century, large-scale real estate and infrastructure construction have made China the world's largest end market for excavators and boosted the development of China's local excavator industry.

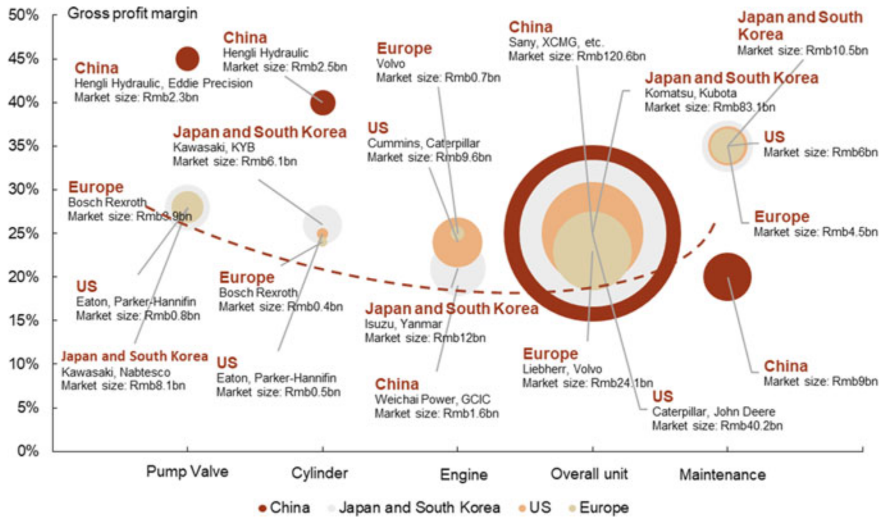

Fig. 12.5 Global landscape of excavator value chain. *Note* Bubble sizes indicate 2022 output value; we use 2021 GM data in this figure. *Source* China Construction Machinery Association, corporate filings, CICC Research

Policy-led infrastructure construction created a sizable excavator market in Japan. Japan's infrastructure investment started explosive growth in the 1960s. Over 1960–1990, total output value of Japan's construction industry (calculated based on constant prices) increased to more than JPY40trn from JPY2trn. In the early 1980s, annual excavator sales volume was less than 2,000 units in the US and around 10,000 units in Europe, while local demand in Japan exceeded 40,000 units. By the 1990s, annual output of excavators in Japan was close to 200,000 units. Japan experienced both an ongoing expansion of its local market and entry of domestically made products' into the US and European markets.

Japanese companies overtook overseas rivals. In 1960, the Japanese government announced the opening up of the domestic market. Caterpillar and Mitsubishi established a joint venture and quickly occupied the local market. Japanese companies sharpened their competitiveness by improving product quality, strengthening services, and developing advanced technologies. Excavators have various application scenarios and face different performance requirements as working conditions vary, which benefits local companies that better understand customer needs. Accumulation of technological expertise of suppliers and explosive demand growth contributed to Japan's sizable excavator industry. The rise of excavator OEMs also boosted the growth of Japanese component companies such as oil cylinder company KYB, pump & valve company Kawasaki, and Isuzu and Yanmar in the engine market.

China's real estate and infrastructure investment since the 2000s has made it the world's largest producer of excavators. China also entered a period of large-scale construction in the early 2000s. From 2000 to 2021, fixed-asset investment in China's urban infrastructure increased to more than Rmb17trn from less than

Rmb1trn, and that in real estate development grew to nearly Rmb15trn from less than Rmb500bn. The urbanization rate also rose to 64.7% from 36.2%.

Changes in Chinese companies' market position show a V-shaped pattern. Before the 1990s, China achieved independent supply through approaches such as introducing technologies. Following greater amounts of foreign investment and an influx of used Japanese excavators in the 1990s, China's excavator market underwent a slump in the localization rate to 6% in 2000 from previous 100%. Domestic demand grew rapidly amid macroeconomic stimulus. Chinese OEMs were presented with new opportunities after overseas companies faced capacity shortage. Small- and medium-sized excavators have largely achieved import substitution as domestic OEMs accumulated manufacturing techniques. However, the localization rates for large excavators used in mines are relatively low due to high shutdown costs. Leading companies such as Sany, XCMG, Zoomlion, and LiuGong Group stepped up efforts to expand into overseas markets. Sany exported more than 20,000 units of excavators in 2021.

Domestic production of components slower than that of complete machines; Japan remains the largest supplier in the global market. High-end hydraulic components and engines have high requirements for technologies and manufacturing techniques. Outstanding domestic companies such as Hengli have achieved import substitution of hydraulic cylinders after more than 20 years of continuous development. Regarding pumps and valve products, Hengli held a 50% share in the small excavator market and less than 20% in the medium and large excavator markets. Kawasaki and Rexroth still enjoy solid market share. China has yet to start the independent supply of engines in bulk. Heavy-duty truck (HDT) engine manufacturers (such as Weichai) have reported shipments and are upgrading their manufacturing techniques. We think domestic high-end components are not yet positioned for global mass production. In addition to supplying hydraulic cylinders in China, Hengli also exports products directly to Japanese OEMs. We expect Hengli to gradually expand its presence in overseas markets backed by competitive products.

Similar to excavator equipment, China's machine tool industry also had a V-shaped localization rate pattern. The difference is that Chinese excavator manufacturers are now globally competitive, and their position in overseas markets is gradually improving. However, China's high-end machine tool market remains in the initial stages compared with the excavator industry. The underlying reasons leading to the gap merit further study, in our view (Fig. 12.6).

12.2.4 PV equipment Industry

12.2.4.1 Smile Curve: Ongoing Leadership in the Global Value Chain

The PV equipment value chain mainly includes components and complete machines. Silicon materials are made into silicon ingots and silicon rods through crystal-pulling

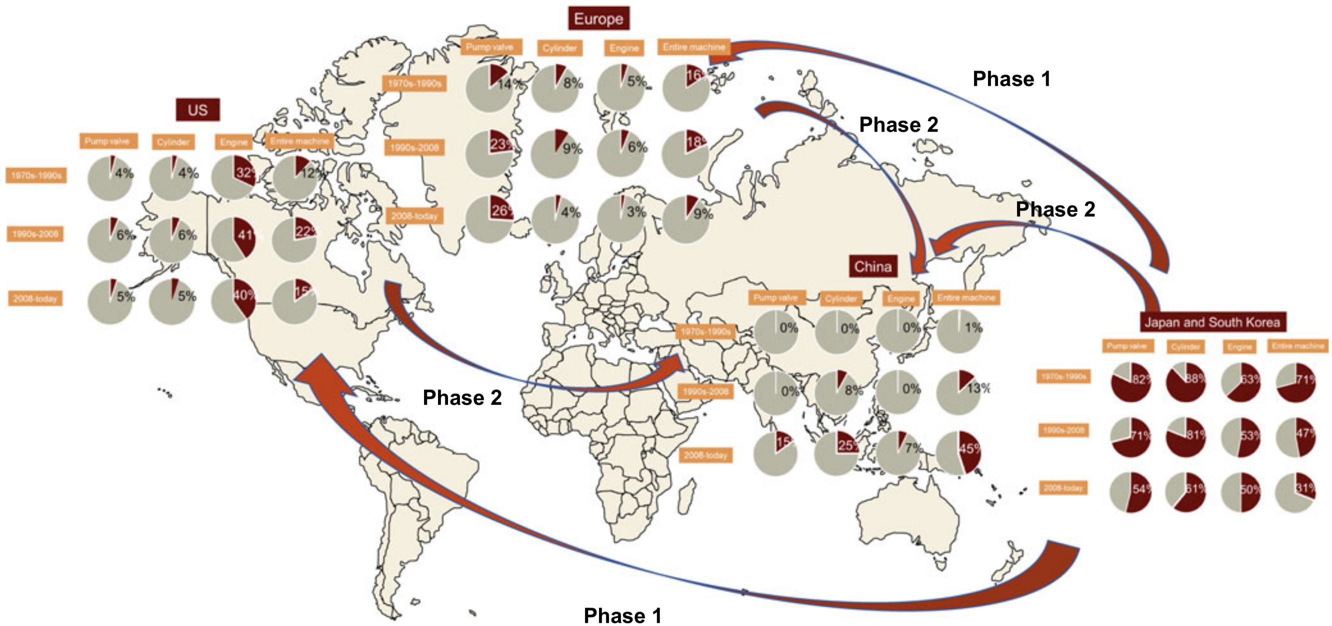

Fig. 12.6 Evolution of the global excavator value chain. *Note* Percentages refer to the proportion of China's output in the world's total. *Source* China Construction Machinery Association, Off-highway Research, CICC Research

equipment. They are cut into PV silicon wafers by slicing equipment, then manufactured into module products through cell and module equipment. The finished products are eventually used in PV power stations. After decades of technological innovations, China's PV equipment industry has achieved a high degree of import substitution. Only a small number of components and auxiliary consumables rely on imports.

China leads global rivals in the output value of PV equipment. In China, most PV equipment has been provided by domestic manufacturers since 2018. Chinese PV equipment companies can independently supply turnkey production lines. At the same time, the number of overseas manufacturers' product lines have gradually declined. Chinese PV equipment manufacturers enjoy both large local demand and rising overseas orders and market share. Kayex, a representative silicon wafer equipment manufacturer in the US, was acquired by LINTON Technologies in 2013. In 2021, S.C New Energy Technology, a cell equipment manufacturer, generated revenue eight times that of Singulus Tech, a representative German manufacturer.

Localization rate of components and auxiliary consumables has yet to increase. China has made significant progress in the import substitution of PV equipment's core components, auxiliary materials, and consumables. Some segments still require a high proportion of imported components and materials. In the silicon wafer equipment segment, high-purity quartz sand is currently monopolized by Unimin (the US) and TQC (Norway). In addition, most power sources of PV cell equipment are imported. The localization of low-temperature silver paste for HJT cells is still underway (Fig. 12.7).

12.2.4.2 Evolution of Value Chain: Policy Support, Growth in Demand, and Technological Transformation Foster a Large Value Chain

Over the past 20 years, the PV equipment value chain gradually shifted from the US, Japan, and Germany to China. As downstream production capacity is mainly located in China, favorable conditions exist for domestic equipment manufacturers to overtake overseas companies, in our view. Data from the China Photovoltaic Industry Association shows that China's capacity of silicon wafers, cells, and modules accounted for 98.1%, 85.1%, and 77.2% of the world's total at end-2021. Domestic equipment manufacturers are in relatively close proximity to customers. They have abundant accumulated process knowledge and achieved faster technological upgrades, resulting in advantages in cost reduction and efficiency enhancement. Domestic manufacturers have lowered the selling prices of their PERC and HJT PV cell equipment to around Rmb120mn/GW and Rmb400mn/GW, compared with around Rmb570mn/GW and Rmb1bn/GW for previously imported equipment in 2021. International PV equipment companies exited from this business under competitive pressure from Chinese firms. For example, Meyer Burger announced in 2021 that it would transition from a PV equipment supplier into a PV module manufacturer. Amtech announced the sale of its Tempress solar business department

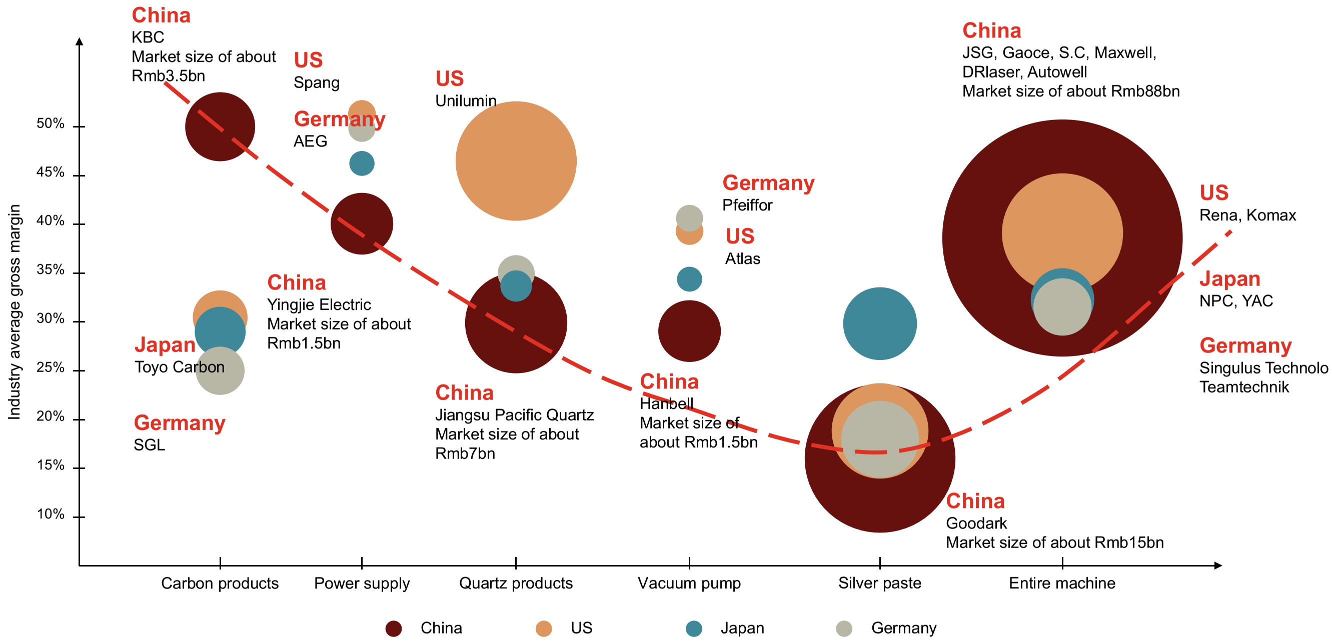

Fig. 12.7 Global landscape of PV equipment value chain. *Note* Bubble sizes indicate 2022 output value; we use 2021 GM data in this figure. *Source* China Photovoltaic Industry Association, Corporate filings, CICC Research

in 2020. We estimate the global market share of China's PV equipment at 80–90%, with the presence in overseas markets expanding.

China to be the first country to apply emerging cell technologies in mass production; Chinese PV equipment manufacturers provide turnkey solutions. New cell technologies bring higher photoelectric conversion efficiency and boost the upside potential of future efficiency improvement, including TOPCon, HJT, and XBC technologies. Sanyo first developed HJT cells in the early 1990s, but failed to achieve mass production outside Japan. The company was acquired by Panasonic in 2015. Chinese manufacturers began to increase R&D activities and investment in HJT technology after Sanyo's patent protection ended. Golden Glass and Huasun Solar have established production lines with GW-level capacity. Maxwell developed turnkey solutions for HJT cell equipment and secured a 70% market share in this segment in 2021.

Demand: Surging domestic PV installations and demand for economic efficiency accelerated changes in the PV equipment value chain. Statistics from China's National Energy Administration (NEA) show that the country's newly installed capacity of PV projects connected to power grids reached about 53GW in 2021, ranking No.1 in the world for nine consecutive years. In 2018, China's newly installed capacity declined due to the "531" policy , while other countries increased incremental installed capacity amid falling product prices, boosting global PV equipment investment growth. In 2018, China's equipment technologies for crystalline silicon cells and other segments surpassed those of overseas rivals, and domestic technologies and production capacity increased further.

Supply: China's PV equipment segment is more technologically advanced and cost-effective than its overseas counterparts amid ongoing technological innovations. Driven by technological improvement, production automation, and intelligent transformation, domestic PV equipment manufacturers gradually equaled or even exceeded overseas equipment names in technological competitiveness, and they also enjoy price advantages. Domestic PV equipment manufacturers are also making rapid progress in developing new cell technologies. S.C New Energy Technology's PE-poly equipment and DR Laser's second laser doping technique for TOPCon cells have been recognized by downstream clients. Maxwell's single-sided crystal-ceramic technology for HJT batteries was adopted by Golden Glass and Huasun Solar. In particular, emerging metallization techniques such as laser transfer printing and copper electroplating are rapidly being applied to produce solar cells, facilitating lower manufacturing costs and higher PV battery efficiency.

Policies: China has introduced a number of policies related to achieving carbon neutrality and boosting intelligent manufacturing, shoring up the PV industry. The State Council issued eight policy measures in July 2013 specifying that China's total installed capacity should exceed 35GW in 2015. In July 2017, China targeted installing 86.5GW of PV capacity during 2017–2020. In 2018, the "531" policy was promulgated, followed by falling PV installation subsidies, fiercer competition along the PV industry chain, and lower prices. PV equipment companies were compelled to upgrade technologies, reduce costs, and improve efficiency. In 2016, in a guideline on emerging sectors of strategic importance during the 13th

Five-Year Plan period (2016-20), China proposed promoting collaboration in applied research between universities and different industry sectors, improving the design and manufacturing of key supporting equipment, solving technological bottlenecks of advanced crystalline silicon cells and key cell equipment, and promoting the industrialization of emerging solar utilization technologies and materials with high efficiency and low costs.

China's PV equipment industry achieved rapid development in a relatively short period, which forged world-leading competitiveness with relatively full-fledged supporting capabilities along the industry chain. This is quite different from the experience of large aircraft and robot industries. The possible reasons are elaborated in Section 3 (Fig. 12.8)

12.2.5 Outlook for Changes in the Equipment Manufacturing Industry Chain

The aforementioned changes in the industrial value chain show that industries have migrated to China from the US, Japan, and Europe as China's market size and manufacturing capabilities grow. **Due to trade frictions, some industries have been passively relocated overseas.** For example, after US-China trade frictions escalated in 2018, the US imposed tariffs of 7–25% on the hardware tool industry, of which more than 80% of global capacity originated in China. As a result, domestic and overseas companies stepped up efforts to expand their presence in Southeast Asian countries such as Vietnam and Thailand to avoid tariffs, including Techtronic Industries, Chervon Holdings, GreatStar, and Stanley Black & Decker.

Enterprises in some industries took the initiative to build manufacturing bases overseas to explore local markets. Since 2015, domestic construction machinery OEMs have been accelerating their expansion into overseas markets. They built production facilities in countries such as India and Indonesia to reach out to local markets. In the past two years, Europe has been focusing on the construction of automotive battery capacity. Chinese equipment companies enjoy advantages in capacity and product categories, delivering integrated equipment and services and winning recognition from European customers. Leading domestic equipment manufacturers have started to plan construction of overseas factories.

However, in most industries, domestic and foreign companies maintain relatively stable production capacity in China, exhibiting little pressure from industries migrating overseas. China remains attractive to equipment manufacturing companies as it still boasts a sizable market and cost advantages. In recent years, some of China's manufacturing industries have been relocated to Vietnam and other Southeast Asian countries. These transferred segments mainly have low barriers to

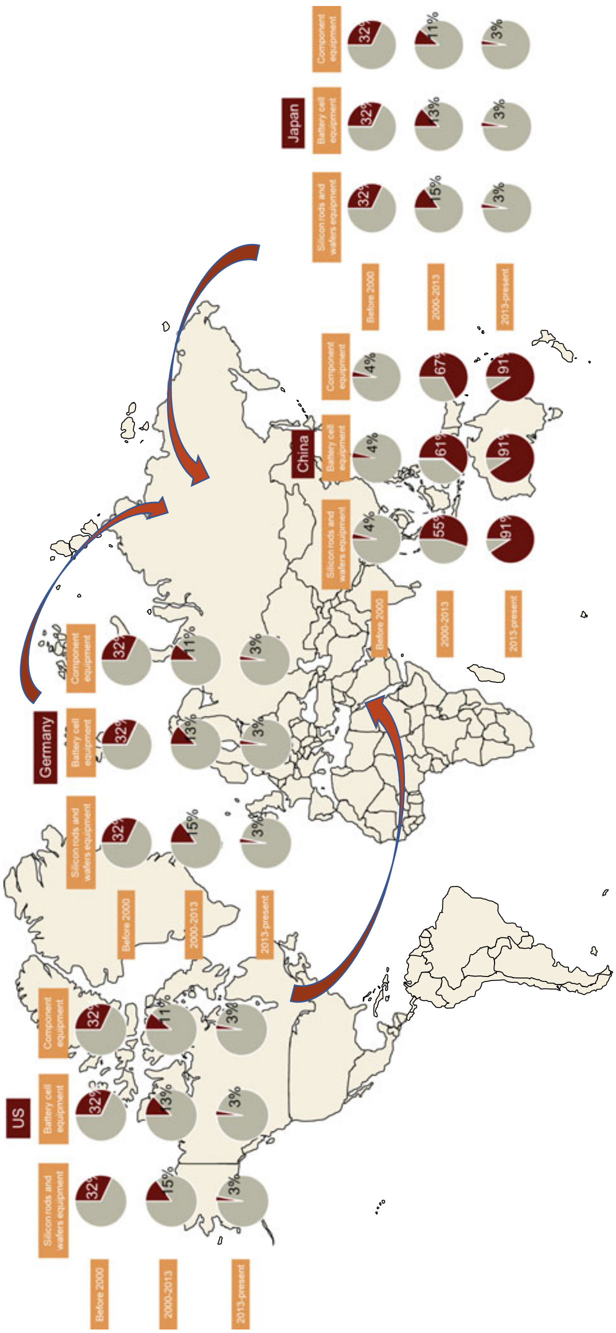

Fig. 12.8 Evolution of the global PV equipment value chain. *Note* Percentages refer to the proportion of China's output in the world's total. *Source* China Photovoltaic Industry Association, CICC Research

entry for supply chains and a high proportion of labor costs.[3] The machinery equipment value chain is a complex system and has higher supply chain requirements due to customized needs from downstream segments. For example, China maintains its advantages in the container industry, which is not necessarily high-tech as it is sensitive to supply chains and costs rather than labor costs. Similarly, China keeps its dominant position in the aforementioned hardware tool industry despite the global supply chain being reshaped due to the impact of tariffs. Given the capacity of existing supply chains in Southeast Asia, OEMs only plan to build 10–20% of overall capacity in relevant countries, mainly for products subject to higher tariffs. Tariffs and other factors have brought about an irreversible reshaping of the global distribution pattern in the hardware tool industry, but regional manufacturing advantages and the overall structure of different regions have remained largely intact.

Against the backdrop of relocation, we believe policies should be adopted differently for industries with different strategic positions.

12.3 Analysis of Equipment Manufacturing Industry Drivers From a Latecomer's Perspective

The first two sections elaborate on the status and catalysts of China's equipment manufacturing industry from the development of different segments and the industry as a whole. Economies of scale play a significant role in advancing industrial development. We also note a sizable divergence in the independent supply capacity among different industries in China despite large domestic markets. In other words, economies of scale can effectively promote industrial development, but does not ensure successful industries.

In this section, we address issues including the underlying factors as to why the computer numerical control (CNC) machine tools, robots, and large aircraft industries remain dominated by overseas companies while the alternative energy equipment, HSR, and shield machine industries have achieved a high degree of import substitution and established relatively full-fledged supply capacity along the value chain despite sharing the same broader market conditions and supporting industry chains. What insights can be used for the future development and policy formulation of China's equipment manufacturing industry? In the following section, we analyze drivers of the equipment manufacturing industry based on the previous review of changes in sub-sectors and other industries.

[3] SHI Zhan. *Spillover: The future of Chinese manufacture industry*. CITIC Press Group, 2020.

12.3.1 Assumptions: Core Drivers of Equipment Manufacturing Industry Lie in Ongoing Technological Accumulation

Technological accumulation is an important source of core competitiveness in the equipment manufacturing industry. From the perspective of technical paradigms, University of Sussex professor Keith Pavitt[4] believes equipment enterprises are typical specialized suppliers. Their competitive advantages depend to a large extent on firm-specific skills, which are reflected in product design, continuous improvement in product reliability, and rapid response to user needs and feedback. We think equipment companies make progress in technological upgrades by relying on practices and applications with continuous trial and error. Therefore, practical applications of equipment in downstream industries constitute a prerequisite for the continuous improvement of equipment strength, and the two are mutually reinforcing.

China's equipment companies participated in global competition as "latecomers in technological development". As overseas countries commenced industrialization earlier than China, foreign equipment companies accumulated technologies for a longer period than domestic firms did. After the 1990s, downstream market demand rapidly expanded in China's manufacturing industry, and overseas companies entered the Chinese market through exports, technology transfer, and foreign investment. Thanks to competitive products, foreign investors accelerated the replacement of their Chinese counterparts, resulting in a strong "demand crowding-out effect".[5] As such, fledging domestic equipment companies were technological latecomers amid intense foreign competition, leading to their common role as "technology chasers" initially. The history of the alternative energy equipment, HSR, and excavator industries tells us that if domestic firms can shake overseas rivals' market dominance, they can give full play to their unique advantages of large end-markets, high-value-for-money products, and low engineer costs, as well as accumulate numerous techniques, thereby surpassing overseas companies in terms of technologies and market share.

[4] Pavitt, Keith. "Sectoral patterns of technical change: towards a taxonomy and a theory." *Research policy* 13.6 (1984): 343-373.

[5] SUN Xiaohua, and LI Chuanjie. "Effective Demand Scale, Double Demand Structure, and Industrial Innovation Ability: The Evidence from Chinese Equipment Manufacturing Industry." *Science Research Management* 1(2010):11.

12.3.2 Internal Cause Analysis: Explaining Technological Gap Between Latecomers and First Movers Through Four Industrial Characteristics

As China is a latecomer in equipment industry growth, we think its opportunities for technological accumulation mainly depend on: (1) Initial technological gap; (2) characteristics of downstream demand; (3) core supporting resources and competitive pressure from foreign capital; and (4) relevant policies, which could affect the accumulation progress of domestic equipment firms by regulating demand and supply.

12.3.2.1 Breadth of Initial Technological Gap Determines the Difficulty of Starting Technology Accumulation

Second movers often face a cold start problem.[6] Foreign brands with technological advantages tend to hinder technology diffusion, and users are hesitant to buy complex products manufactured by latecomers. As a result, latecomers often find it difficult to accumulate manufacturing techniques in the early stages relying on their capabilities.[7]

The size of the initial technological gap is largely determined by the time lag between the industry's initial development and the industry scale. For example, China's LiB equipment industry began to develop in the early 2000s, and the installed capacity in China's domestic market since 2015 has reached dozens of times that in Japan and South Korea. This provides relatively favorable conditions for the accumulation of technological expertise of domestic LiB firms. As a result, the initial technological gap between Chinese and foreign LiB companies was relatively small, and Chinese firms rapidly caught up with overseas rivals fueled by economies of scale.

However, Chinese excavator and CNC machine tool companies experienced large technological gaps when they started to expand. China accelerated urbanization around 2000, driving up annual domestic excavator sales volume to over 10,000 units from about 2,000 units in the 1990s. Therefore, a significant technological gap exists between China's excavator companies and overseas rivals, which was formed early on and is difficult to bridge simply through economies of scale. The same is also true for the machine tool, robot, and large aircraft industries, in our opinion.

However, technological changes can narrow the gap and sometimes lead to the replacement of industry leaders. For example, the rapid technological iterations in the PV industry could change the time-based technological gap between followers and leaders. Therefore, we believe it is relatively easy for domestic companies to catch

[6] The Cold Start Problem – also known as the "chicken and egg" problem – describes a paradox found in two-sided business models.

[7] OUYANG Taohua, and ZENG Delin. "Revealing Hardships and Glory of China's shield machine technological catch-up." *Management World* 37.8(2021):14.

up with rivals despite sizable gaps at present. Industries should also pay attention to potential technological changes in the future, and second-mover industries could seek opportunities to narrow the gaps. Leading companies should concentrate on how to retain technological leadership.

12.3.2.2 Demand: Downstream Companies' Trial-And-Error Costs and Existence of Differentiated Demand

The global competitiveness of China's excavator and machine tool industries diverged during the past 20 years, though the two industries both lag their overseas counterparts in technological development. We believe downstream demand could affect companies' accumulation of technological expertise and catch-up in capturing market share. Latecomers usually have lower technology levels than leading companies, and they generally make breakthroughs in the market by offering value-for-money products. However, not all industries offer companies the opportunity to gain market share with cheap products due to downstream clients' trial-and-error costs. In industries with high trial-and-error costs, it takes latecomers more time to make breakthroughs in the market, making it more difficult to start a positive cycle between technological accumulation and market share acquisition.

Downstream firms often show strong risk aversion as they cannot accurately predict the performance and reliability of equipment. This leads to a vicious spiral in which opportunities in the domestic market decline as buyers prefer overseas brands due to risk aversion, resulting in local companies lacking successful track records and independent innovation capabilities. Downstream segments of different equipment subsectors also show varying characteristics. For example, differences in high-end CNC machine tools will negatively affect the processing accuracy and yield of production lines, and consequently, the economic benefits of downstream companies using these machine tools. The difference in machine tool prices could reach Rmb1mn, which could possibly affect the final economic benefits of the entire production line by Rmb10mn. Therefore, companies bear high costs in trying new high-end machine tools, making it difficult for domestic machine tool companies to tap potential markets, in our opinion.

As for positive effects, we think local enterprises may benefit from the differences between local demand and mature overseas demand. For example, excavators and shield machines are usually designed according to local geological conditions and construction environments. Domestic companies' proximity to the market enables them to recognize local demand and develop innovative or customized products more easily. Furthermore, the customized development of products relies heavily on engineers, and labor costs, efficiency, and supply vary greatly at home and abroad. New energy equipment is also a customized product, which can be innovated by suppliers based on downstream clients' specific needs, such as production capacity expansion, better product performance, and lower cost. It is difficult for overseas first-mover companies to quickly meet the large-scale customized development needs of domestic downstream companies due to limited production capacity and high wages of engineers. As such, products of domestic equipment companies may potentially be used in downstream segments.

12.3.2.3 Supply: Core Supporting Resources Ensure Industry Security; Supply Bottleneck of Foreign Capital Brings Opportunities

Core resources of the equipment manufacturing industry include key technologies, components, basic materials, and high-level skilled labor. For example, CNC systems of domestic machine tools are usually imported from Japanese manufacturers such as Fanuc and Mitsubishi. They are often sold after downshifting, with limited available functions and parameters that restrict the market development of domestic machine tool companies. We think components with low added value but irreplaceable functions also merit attention, in our view, as these industries may face major technology bottlenecks if their sources of supply are relatively concentrated (such as power supply and vacuum pumps used in PV equipment).

Another factor that plays a role is the supply shortage of foreign companies, which provides a valuable window of opportunity for domestic companies as followers. For example, downstream segments of the excavator industry, including real estate and infrastructure construction, are mainly affected by macro policies. Demand in these segments is difficult to forecast and fluctuates sharply. Industry growth could double at times, leading to relatively insufficient foreign production capacity. China has experienced three large-scale upcycles in the real estate and infrastructure sectors since 2000. The localization rate of domestic excavator companies increased rapidly during the period, as did that for hydraulic cylinders (a core component). In the past two years, the COVID-19 pandemic caused lower efficiency of the global supply chain and disruptions to overseas supply, further weighing on foreign companies' supply capacity in China. We think this provides opportunities for domestic companies' products to be used by downstream clients.

Certain policy measures could facilitate the accumulation of technological expertise for domestic companies. When China developed the HSR industry in the early 2000s, the Ministry of Railways obtained core technologies for high-speed electric multiple units (EMUs) with speeds of 250 km/h and 350 km/h from Bombardier (Canada), Kawasaki (Japan), Alstom (France), and Siemens (Germany) via two rounds of technology transfer by leveraging its advantages in market size and centralized procurement. Since then, China independently developed high-speed EMUs and established a relatively complete value chain through technology introduction, absorption, innovation, as well as joint research by multiple market participants. China used its self-developed China Railway High-speed Train and Fuxing Electric Multiple Unit in most of the projects during the stage of rapid HSR construction. As of end-2021, the cumulative HSR mileage in China exceeded 40,000 km, accounting for more than 60% of the world's total. This experience has helped China establish a leading position in the global HSR market, in our view.

12.3.2.4 Industrial Policies Affect Companies' Technological Accumulation by Regulating Supply and Demand

Based on the characteristics of supply and demand, we have analyzed the factors that affect companies' continuous technological accumulation. We think policies can help local companies achieve this and catch up with overseas rivals by altering demand or supply conditions. For example, China granted renewable energy subsidies to customers, boosting rapid domestic market expansion and creating a wide range of application scenarios for renewable energy equipment. Supply cultivation policies (e.g., industry-university collaboration in research) can help break the supply bottleneck of core resources, enhance customer confidence, and lower costs of trial and error in downstream industries.

The technological gap between new energy and laser equipment manufacturers and their foreign counterparts was relatively small in the early stages. Against the backdrop of booming domestic demand and low trial-and-error costs in downstream industries, domestic companies quickly acquired a large amount of technical expertise and caught up with foreign firms. Although a large gap existed between excavator producers and their global rivals in the early stages, small- and medium-sized excavators were the first to benefit from increasing localization rates thanks to: (1) Low trial-and-error costs in downstream segments; (2) extensive innovations made by excavator manufacturers to meet the differentiated needs of the domestic market; and (3) certain overseas supply bottlenecks. As for the HSR and shield machine industries requiring complex technologies, favorable domestic policies changed the trial-and-error costs and willingness of downstream clients, shoring up trials of domestically made equipment and technological accumulation.

In contrast, the domestic machine tool, robot, and large aircraft industries face a latecomer problem due to high requirements for product reliability, high trial-and-error costs for downstream owners, and varying degrees of technology bottlenecks in core components and basic materials.

Chapter 13
New Energy: Security Issues Amid Green Transition and Energy Crisis

Abstract Background: Amid the trend of deglobalization, the global energy industry should ensure the security of energy supply while enhancing efficiency. The world is shifting to new energy from fossil fuels. Unlike fossil fuels, of which supplies are limited, new energy comes from inexhaustible resources and depends upon the manufacturing of equipment. As a result, the global energy industry is shifting its focus to optimizing energy equipment manufacturing from simple resource consumption. Against such a background, new energy equipment manufacturing plays a more crucial role in energy security issues.

Security risks facing China's new energy industry chain: We think the vertical risks in China's new energy industry chain are generally manageable as the industry chain is comprehensive, with a high degree of vertical integration. Some raw and auxiliary material segments may be subject to constraints from overseas countries in terms of resources, technologies, and patents. For these segments, we expect related companies to reduce risks by upgrading technologies or developing alternative materials. Compared with vertical risks, we think that horizontal risks need more attention.

In 2021, China exported 55% and 20% of its photovoltaic (PV) and lithium-ion battery (LiB) products to overseas markets. However, with the trend of deglobalization, some countries have repeatedly imposed tariffs on China's new energy products to raise China's trading costs, and have increased subsidies to local new energy industries after assessing the vertical risks their own industry chains might face. This may convert the supply–demand mismatch in China's new energy industry chain into horizontal risks.

Solutions to mitigate the risks: Mature capacity is moving to regions with lower production and trading costs driven by market competition. We expect Chinese companies to move their mature capacity to Southeast Asia and maintain the competitive advantages of their mature capacity in the global new energy industry chain. In addition, we suggest that domestic companies maintain their leading positions and strengthen the competitive advantages of their advanced new energy technologies via

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incremental and radical innovations. In our opinion, the development and success of China's new energy industry chain might be attributed to related companies' cost and technological advantages amid policy tailwinds and economies of scale. Therefore, tapping domestic demand, breaking through the bottlenecks that restrict the growth of domestic demand, and enhancing China's position as the world's largest new energy market are crucial to the new energy industry chain.

We expect the government to launch policies to optimize the trading and business environment required for the transfer of mature production capacity and to increase funds for skilled personnel required for the upgrading of advanced technologies in China. We also recommend policy support for the development of power infrastructure facilities and power consumption facilities as the development of the infrastructure could boost end-market demand. In addition, the government could also step up efforts to mitigate vertical and horizontal risks facing China's new energy industry chain.

Keyword New energy · Photovoltaic · Lithium battery · Advanced technologies

13.1 The Overall Context and Security Issues Facing China's New Energy Industry Chain

13.1.1 Security Issues Amid Green Transition and Energy Crisis

Energy security is closely related to social progress and economic development. The Russia-Ukraine conflict that began in 2022 reveals the European energy industry's overreliance on a single energy supplier and related security problems. In the EU, natural gas accounts for 20% of primary energy consumption (Eurostat data). However, 40% of the natural gas consumed by Europe was imported from Russia in 2021 (Eurostat data). Due to the Russia-Ukraine conflict, the monthly average Dutch TTF natural gas price over January–September 2022 increased by 136%, resulting in energy and electricity cost spikes in Europe. Over January–September 2022, wholesale electricity prices in European countries increased by 36–85%, while residential electricity rates increased by 32%. The energy crisis has significantly impacted Europe's economy and livelihoods, and has also sounded the alarm bell over energy security for countries around the world. At present, governments of many countries are calling for energy independence.

Amid the green transition trend, new energy is replacing traditional energy as a means to safeguard energy security. Many countries have stepped up efforts towards green transformation since 2020, expecting to drive their economic recovery. Europe, China, Japan, and South Korea have announced their goals to achieve carbon neutrality. We expect growth in LiB and PV demand to continue to accelerate in the next decade. The International Energy Agency (IEA) and China Photovoltaic

Industry Association (CPIA) estimate that global LiB and PV demand will grow at CAGRs of 26.0% and 14.9% over 2021–2025 (Fig. 13.1). **Against the backdrop of global green transition, we expect solar power, wind power, LiB, etc. to replace traditional energy in fields of electricity and transportation. The shift to new energy as the main sources of energy also reflects the current crucial role of new energy in energy security issues.**

Traditional energy is limited and exhaustible. A country's supply of fossil fuels is limited by its resource reserves, ore grades, as well as difficulty of extraction. Fossil fuel resources cannot move to other places once they are formed. In contrast, new energy sources such as solar, wind, and LiB are inexhaustible. The supply of new energy is determined by costs of factors of production, economies of scale, expertise and technology accumulation, and supporting facilities, and equipment manufacturing capacity can be transferred. **In our opinion, new energy provides countries around the world with more "equal" opportunities to address energy security and energy independence.**

Globalization enables China to trade its high-quality and low-cost new energy products with overseas countries with few constraints, and to establish a leading position in the global new energy supply system. However, there is a trend towards

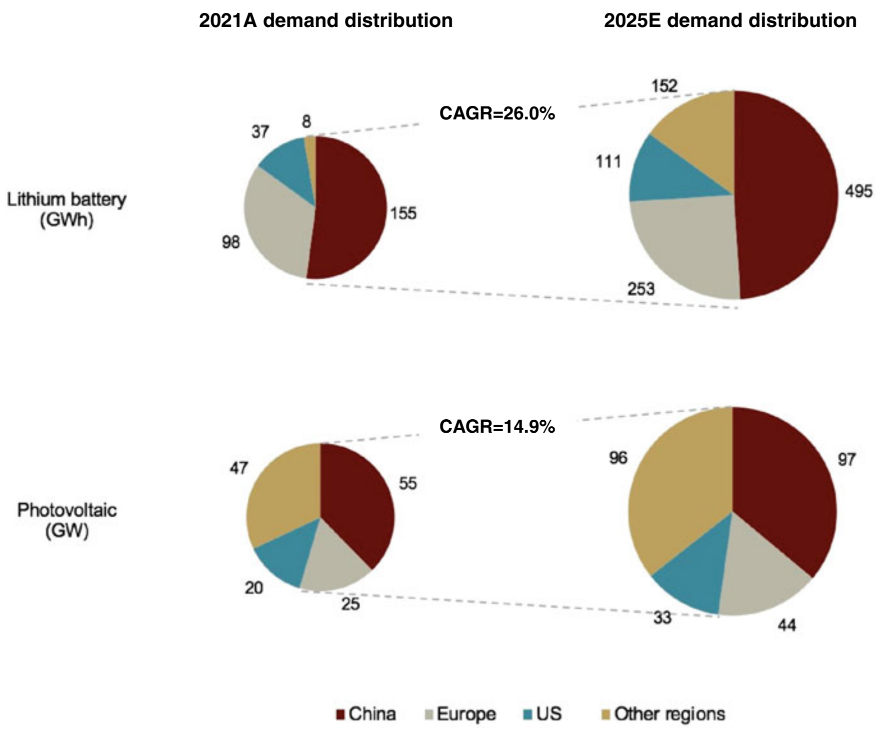

Fig. 13.1 LiB and PV demand forecasts. *Source* IEA, CPIA, CICC Research

deglobalization at present, and the impact of the Russia-Ukraine conflict on Europe's energy system has aroused concerns among other countries about their reliance on external new energy supply (including new energy imported from China). **Therefore, the security of China's new energy industry chain has become a hot topic.**

13.1.2 Vertical Risks Controllable, Deglobalization Exacerbates Horizontal Risks

In 2021, the annual output value of China's PV, LiB, and wind power manufacturing segments approached Rmb750bn, Rmb600bn, and Rmb200bn,[1] with the proportion of exports at around 55%, 20%, and 5% based on our estimation. From the perspective of output value and export dependence, PV and LiB are the two segments in the industry chain most likely to be affected by security issues in the new energy manufacturing industry. Our analysis below focuses on the two segments.

The "three-step" development strategy has facilitated the rapid development of China's new energy industry chain in the past 15 years (Fig. 13.2)**. First step:** During the 11th Five-Year Plan (FYP) period (2006–2010), global production capacity of some energy-consumable manufacturing segments (e.g., anode material graphitization for LiBs) and processing segments (e.g., PV cell modules) was relocated to China given its labor advantages and relatively low electricity costs.

Second step: During the 12th FYP period (2011–2015), China took the lead in reducing the "green premium," which is the additional cost of using new energy over traditional energy, by providing consumption subsidies. The end market for new energy in China expanded rapidly, creating economies of scale in the manufacturing industry. China also accelerated the speed of cost reduction in the industry chain by encouraging "learning by doing", and enhanced its cost advantages in production.

Third step: During the 13th FYP period (2016–2020), the YoY decline in government subsidies catalyzed companies' technological upgrades and cost reduction. In addition, the government set higher goals to encourage companies to improve technologies. As a result, the industry chain entered a high-quality development stage, and the growth momentum of China's LiB and PV segments shifted from production capacity to a focus on R&D.

The "learning by doing" in the new energy manufacturing industry chain and large electricity and transportation markets maximize the effect of the scale-expansion-centered industrial policies and help China create cost and technological advantages. The new energy industry is a typical learning-by-doing industry, which needs substantial demand to support companies' R&D successes and failures. China has large electricity and transportation markets, and has boosted PV and LiB demand by providing consumption subsidies, further expanding the room for new energy companies' trial and error.

[1] Data source: China Photovoltaic Industry Association, Ministry of Industry and Information Technology, and China Electricity Council.

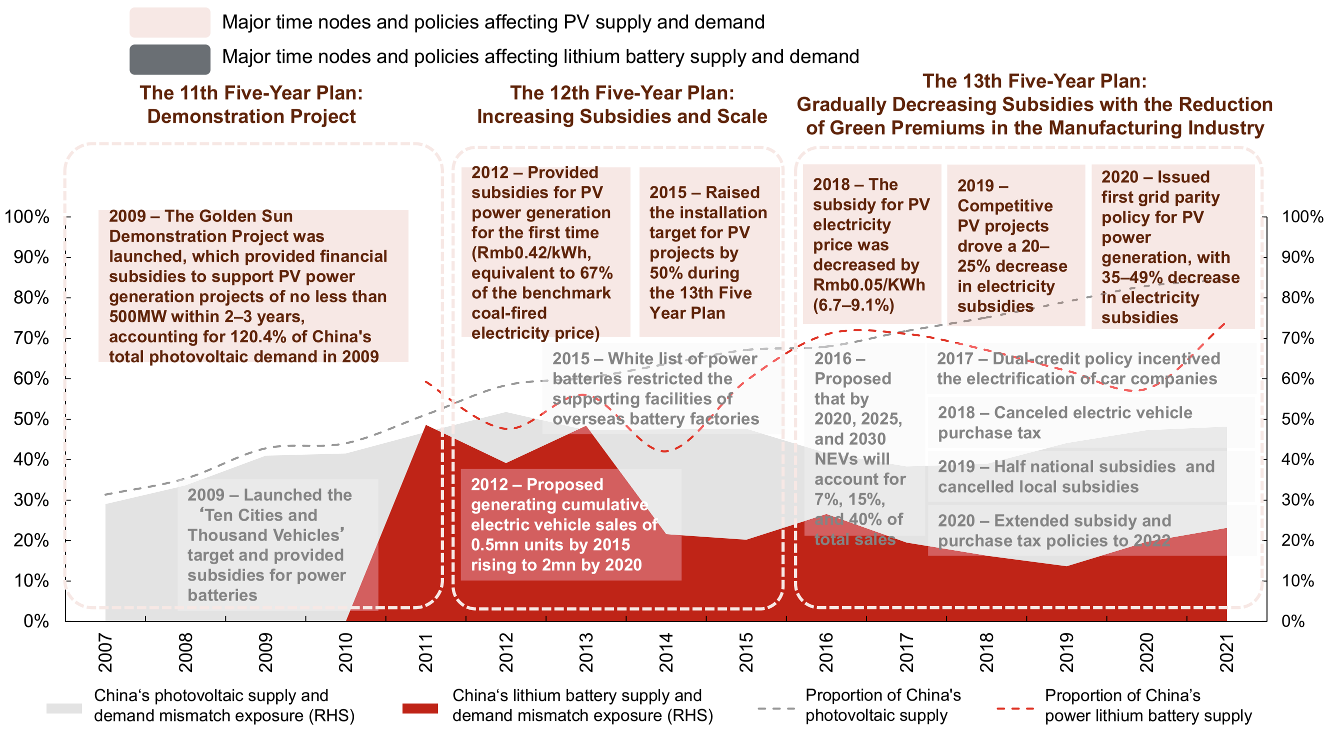

Fig. 13.2 Localization rate in China's new energy industry chain continued to increase in the past 15 years amid policy tailwinds. *Note* (1) The proportion of China's LiB in the global production in 2010 and before is calculated based on the number of batteries released by Wind, and the proportion after 2010 is calculated based on data from China Lithium Battery Industry Development Index (Suining Index) White Paper; (2) The dotted line represents China's market share of supply and the solid line represents China's share of demand; (3) Exposure to supply–demand mismatch =China's share of supply—China's share of demand. *Source* Wind, BNEF, CPCA, CAAM, NEA, China Lithium Battery Industry Development Index (Suining Index) White Paper, GGII, MIIT, CICC Research

Looking at 2017–2022, we note rapid growth in domestic demand and frequent rollout of core technologies, including nickel-rich and ternary battery technologies, cell-to-pack (CTP)/4680 (46 mm in diameter and 80 mm tall) battery technologies, ultra-thin copper foil & composite copper foil technologies, and lithium manganese iron phosphate technologies in the LiB segment. In the PV segment, the frequent rollout of core technologies – including Czochralski method, diamond wire cutting technology, and passivated emitter rear cell (PERC) technology – and the growth of domestic demand were concentrated in 2015–2018.

China's new energy manufacturing industry chain has a high degree of vertical integration. Therefore, except for a few segments, the overall industry chain may face limited vertical import dependence risk. Segments that may still face vertical risks include: (1) Lithium carbonate metal for LiBs and quartz grains for PV quartz crucibles. China relies on imports due to the uneven geographical distribution of related raw materials. (2) Ultra-fine and high-purity materials such as high-purity carbon black conductive agents, mesh cloths (PV battery consumable), and silver powder (OV battery auxiliary material). Chinese companies face high technological barriers in these segments. (3) Lithium iron phosphate (LFP) batteries and monocrystalline solar batteries. In these segments, overseas companies have registered patents for the underlying structure of batteries.

The new energy manufacturing industry chain in China is stepping up efforts to achieve import substitution in components segments. Related companies are developing alternative products or upgrading technology roadmaps. For example, domestic companies are developing carbon nanotubes to reduce reliance on imported carbon black conductive agents and are developing sodium-ion batteries to cope with the shortage of lithium carbonate. As for patent-related problems, we believe that the constraints will ease as product structure upgrades and patents expire.

Although we think that the vertical risks facing China's new energy industry chain are manageable, the green transition and the rise of deglobalization are exacerbating horizontal risks. China's new energy industry chain has been exposed to supply-demand mismatch risks. For the LiB segment, the exposure has been standing at around 20% since 2014. For the PV segment, the exposure remains above 30%. (Fig. 13.3, Fig. 13.4).

The growth of LiB and PV demand will likely accelerate amid the global green transition. This may create growth opportunities for the new energy industry, but will also inevitably increase the industry chain's exposure to horizontal risks. Supply-demand mismatch is a persistent problem challenging China's new energy industry chain. In the past, globalization enabled China to export its LiB and PV products at relatively low trading costs; therefore, horizontal risks did not materialize.

However, given the trend of deglobalization, overseas countries have reexamined their dependence on China's new energy industry chain and have started to take various measures to improve their local capacity and reduce dependence on Chinese imports. They continue to increase subsidies for local new energy industry chains and impose tariffs on new energy products imported from China to push up China's trading costs. In addition, they call for raw material traceability and tracking of a

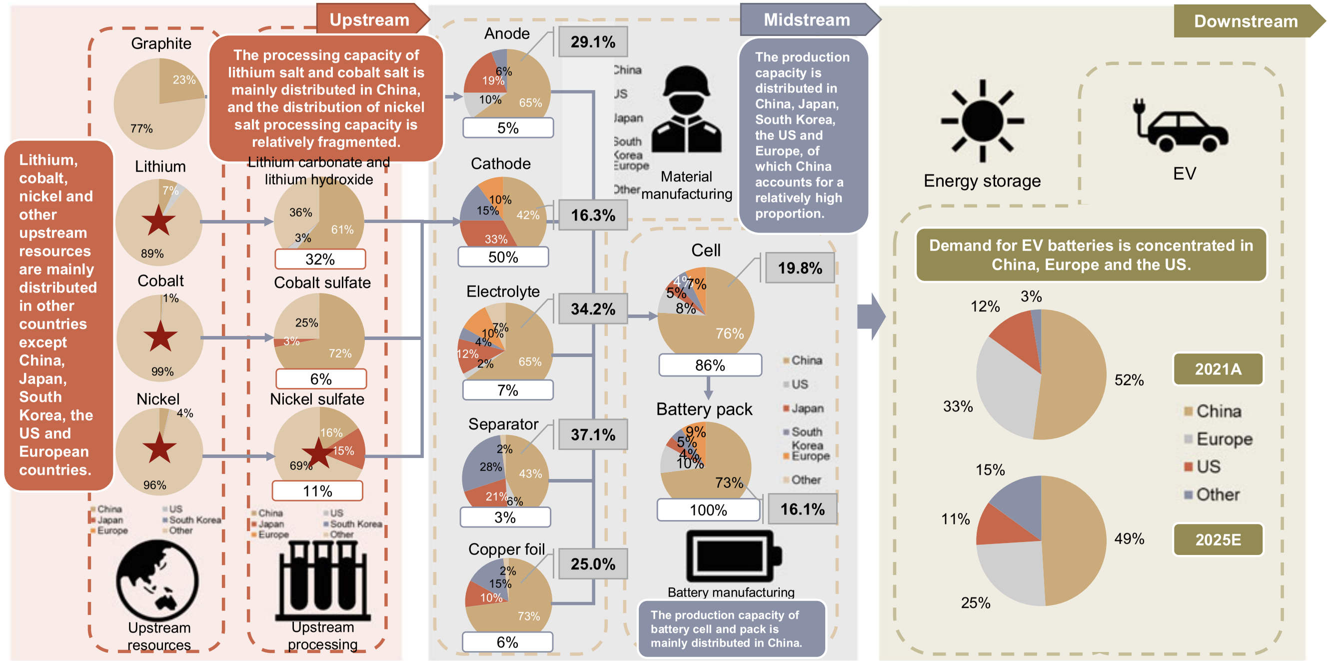

Fig. 13.3 Qualitative and quantitative analysis on the LiB industry chain. *Note* (1) The localization rate in segments marked with red stars is low, and these segments are still facing some vertical risks; (2) The percentage of upstream resources in the figure reflects countries' global share by resource reserves in 2021. The percentage of the rest of upstream resources and midstream resources are countries' global share by national production capacity in 2021. The number in the white box is the ratio between current segment's value and the overall ternary battery pack's value, and the number in the gray box is the GM of this segment in 2021 (we only calculate data of ternary batteries in the battery manufacturing segment). Downstream demand forecast is based on the installed battery capacity data (unit: GWh) predicted by IEA according to different countries' policies for alternative-fuel vehicles. *Source* America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition by U.S. DOE, 100-Day Reviews under Executive Order 14,017 of the US, USGS, EVTank, IEA, CICC Research

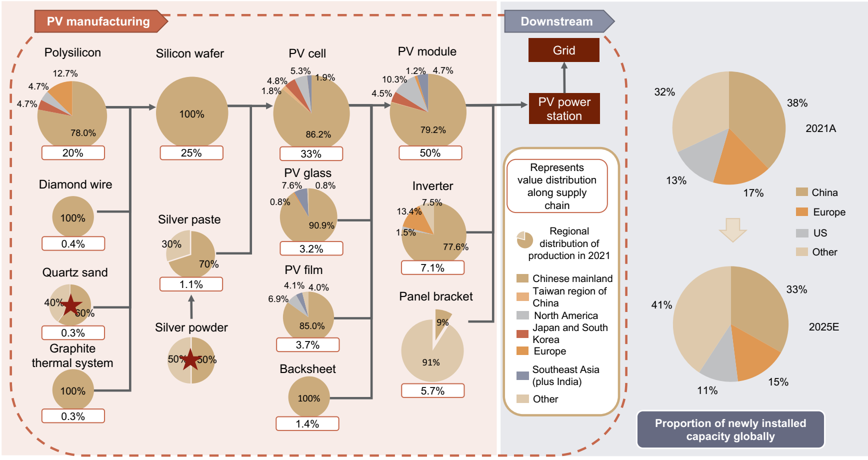

Fig. 13.4 Qualitative and quantitative analysis on the PV industry chain. *Note* The localization rate in segments marked with red five-pointed stars is low, and these segments are still facing some vertical risks. *Source* CPIA, BNEF, Solarzoom, CICC Research

carbon footprint, and require downstream supporting facilities, which will likely increase China's implicit trading costs. We review some policy changes in major countries below.

US: In recent years, the US has continued to place tariffs on LiB and PV products from the Chinese mainland. In addition to planned punitive tariffs on overseas production capacity of Chinese companies, the US government has restricted the origin of raw materials of imported products. In addition, the Biden government signed the Inflation Reduction Act of 2022, proposing to provide a high proportion of cash subsidies (in the first five years) or tax preferential subsidies for local manufactured LiB and PV products. We estimate that the subsidies can cover 30–50% of the end-market cost of PV and 50–70% of the end-market cost of LiBs, and this will significantly reduce the cost of local new energy manufacturers' production capacity.

EU: In September 2022, the EU issued a draft plan proposing to review the origin of raw materials of imported products according to which it would increase the difficulty of exporting new energy products from China after 24 months, and called for building local LiB and PV manufacturing capacity. It also made its intention of building a "carbon border" clear, forcing Chinese companies to completely transform the production, supply, and marketing systems to meet the EU's requirements.

Select emerging markets: India tends to exclude Chinese PV module products from the Indian market by raising basic import tariffs and issuing a "white list" of model and module suppliers. Indonesia has abundant nickel resources, and it will likely impose tariffs on nickel product exports to increase costs of direct exports, expecting to support the development of its local industry chains.

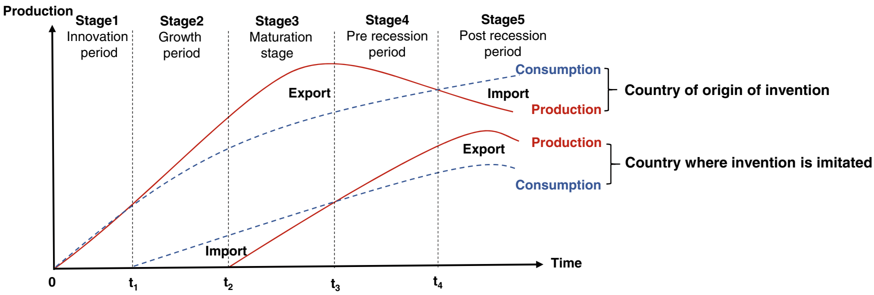

Fig. 13.5 Product life cycle. *Source* Salvatore (1995),[2] CICC Research

13.2 Mitigating Horizontal Risks by Moving Mature Production Capacity to Overseas Markets and Developing Advanced Technologies

We suggest that chinese companies move mature production capacity to overseas markets and develop advanced technologies in China given the current risks facing China's new energy industry chain.

13.2.1 Mature Capacity: Relocating Production to Southeast Asia, Europe, and the US Driven by Rising Trading Costs

According to the product life cycle theory, a product often undergoes the stages of innovation, growth, maturity, and decline during its lifetime. Industrial transfer often occurs at the maturity stage (Fig. 13.5). From 2000 to 2010, consumer batteries from Japanese and South Korean companies and polycrystalline PV modules manufactured in Europe or the US, which had been developed and iterated for several years, gradually began to mature and have laid a foundation for technological development. Therefore, LiB and PV capacity moved to China as China had lower production and trading costs on the back of its advantages in labor, electricity, land, and equipment.

According to our calculation, the LiB manufacturing cost (excluding raw material costs) in China was only around 25–55% of that in Europe, the US, Japan, and South Korea, and the PV module manufacturing cost (excluding raw material costs) in China was only around 42–80% of that in Europe, the US, and India. Due to the relatively low manufacturing costs and the low trading costs amid globalization, LiB and PV capacity transferred to China in 5–10 years, and the industry chains of related upstream materials and auxiliary materials also moved to China after 2015.

[2] Salvatore, Dominick. *International Economics*. Printice-Hall Inc., 1995.

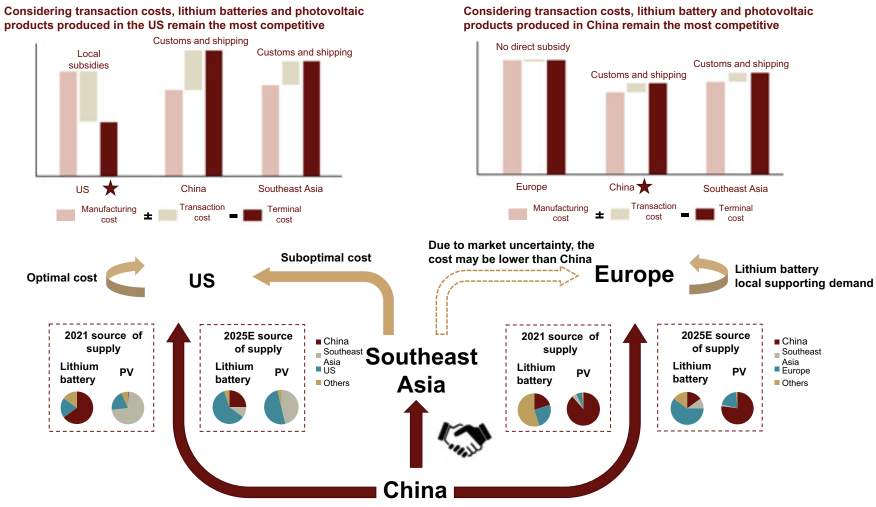

Fig. 13.6 Estimated transfer model of LiB and PV industry chains. *Source* Congress.gov, USITC, European Commission, CICC Research

At present, liquid LiBs and mono PERC PV modules have entered the maturity stage in China, and the trend of deglobalization is pushing up trading costs of Chinese products. Against this backdrop, new energy product manufacturers in China have chosen to move the industry chain to regions outside China. We share our projections below for Chinese companies that adopt the transfer model for mature capacity (Fig. 13.6).

Based on current US tariff and subsidy policies, we calculate that from 2023, the theoretical cost of Chinese LiB and PV products exported to the US will be more than 100% higher than the theoretical cost of local LiB and PV product manufacturers in the US. Given the US Congressional Budget Office's forecast of total subsidies for the local manufacturing industry under the US Inflation Reduction Act of 2022, we calculate that the total amount of its budget targeting PV subsidies corresponds to about 20% of the next 10 years of local demand in the US, or 50% of the expected demand in 2025. Its budget targeting LiB subsidies may cover less than 10% of the next 10 years of local demand in the US. However, we believe that more than 10% of the new energy industry chain will be moved to the US. This means that there will be more production capacity competing for US government subsidies. The long-term direction of relevant policies is not clear at present. If the lucrative subsidies continue, we believe that the US could successfully increase its proportion of local capacity in LiB supply.

The European market has not been affected by large amounts of subsidies or import tariffs. However, downstream of the LiBs in Europe has higher requirements for coordination along the industry chain and local supporting facilities. In addition, EU regulations on batteries and waste batteries and its deal on carbon border tariffs may increase implicit trading costs, driving the LiB industry chain to shift to Europe to support local demand. We estimate that the LiB self-sufficiency ratio in Europe will exceed 50% in 2025. As cost is at the core of the PV industry, Chinese companies at present do not plan to move their PV capacity directly to Europe. In the long term, such a move may depend on whether Europe will implement its raw material traceability proposal and the actual effect of this regulation.

Production costs of PV cells and modules in Southeast Asian countries are only about 5% higher than those in China, and there are currently no Sect. 301 tariffs or anti-dumping and anti-subsidy duties on PV products exported to the US from Southeast Asia (PV modules that are vertically integrated in Southeast Asia and contain zero or few raw and auxiliary materials from China may be exempt from the potential anti-circumvention investigation). Countries with rich nickel resources, such as Indonesia, will likely impose tariffs on the exports of nickel products in the future. We expect Chinese companies to build precursor or cathode manufacturing factories in Indonesia. **In our opinion, the scale of the new energy industry chain in Southeast Asia will likely expand further to meet the needs of Europe and the US.**

13.2.2 Advanced Production Capacity: Upgrading Technologies to Build Advantages Over Mature Capacity Overseas

China's advantages in labor costs and electricity prices may weaken as the country heads for new stage of development. Labor: Due to the aging population and the improved educational level of the population, the cheap labor once readily available for China's manufacturing industry is shrinking. The average salary of workers in China's manufacturing industry increased by 18% in 2019–2021.[3] By comparison, the average salary of workers in the manufacturing industry of Vietnam, Myanmar, and the Philippines only increased by 8%, 5%, and 3%, while that in Malaysia remained the same and Thailand fell 17% in the same period.[4]

Electricity rates: The regulations on prices of energy for industrial and commercial users in China have been loosening since 2021. As a result, ordinary electricity prices for industrial and commercial users in key provinces in China have increased by 10–20%.[5] **In our opinion, Chinese companies must step up their technological innovation to maintain their leading positions in the global new energy industry chain and build stronger competitive advantages over mature capacity overseas. We think there are two key strategies through which China's LiB and PV industries can develop advanced technologies.**

First, incremental innovation. According to the theory of Induced Technical Change (ITC), innovation in the energy industry is to a degree induced by changes

[3] Data source: Wind.

[4] Data source: Wind.

[5] Data source: Wind.

in relative prices of production factors. As relative prices of production factors change, the energy industry will shift to cheaper materials. Therefore, we believe that current new energy-based manufacturing processes with lower energy consumption and higher levels of automation will likely attract more attention and gain larger investment (e.g., box furnaces for LiB anode material graphitization and fluidized bed reactor technology for the PV silicon material segment). **Second, radical innovation.** Next-generation technologies, including solid state LiB technology and perovskite solar cell technology, are less compatible with the mature liquid LiB and crystalline silicon PV cell industry chains and have a disruptive impact on the existing industry chains. At present, China outperforms its overseas rivals in next-generation technologies.

13.3 Solutions to Horizontal Risks: Breaking Constraints, Tapping Domestic Demand

In addition to moving mature capacity outside China and developing advanced technologies, tapping domestic end-market demand for new energy in China is also an important way to reduce horizontal risks facing the manufacturing industry chain. As a result, the energy industry needs to watch out for constraints that potentially limit the growth of domestic new energy demand.

13.3.1 Infrastructure is the Most Critical Factor Deciding the Upper Limit of Mid-To-Long-Term Demand Growth

LiB: The increase in the penetration rate and ownership of passenger alternative-fuel vehicles (AFVs) in China has led to demand for public charging stations. The expansion of public charging infrastructure is crucial to removing consumers' range anxiety and encouraging purchases of AFVs. At present, the insufficient power grid hosting capacity and peak shaving capacity are two major constraints on the infrastructure side, impeding large-scale access to charging facilities and affecting charging convenience and efficiency. (Fig. 13.7).

PV: By 2021, the proportion of new energy in total power generation was 11.7% in China, vs. more than 20% in Europe.[6] However, in 2020–2021, the proportion increased at a growth rate of 2.2ppt per year. Generally speaking, as the proportion reaches 20–25% or higher, the power system's stability, flexibility, and reliability should be upgraded and improved to safely provide more links to new energy generation resources. Therefore, the pressure from the infrastructure

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6 http://www.gessey.com/h-nd-6549.html [Chinese only]; https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics.

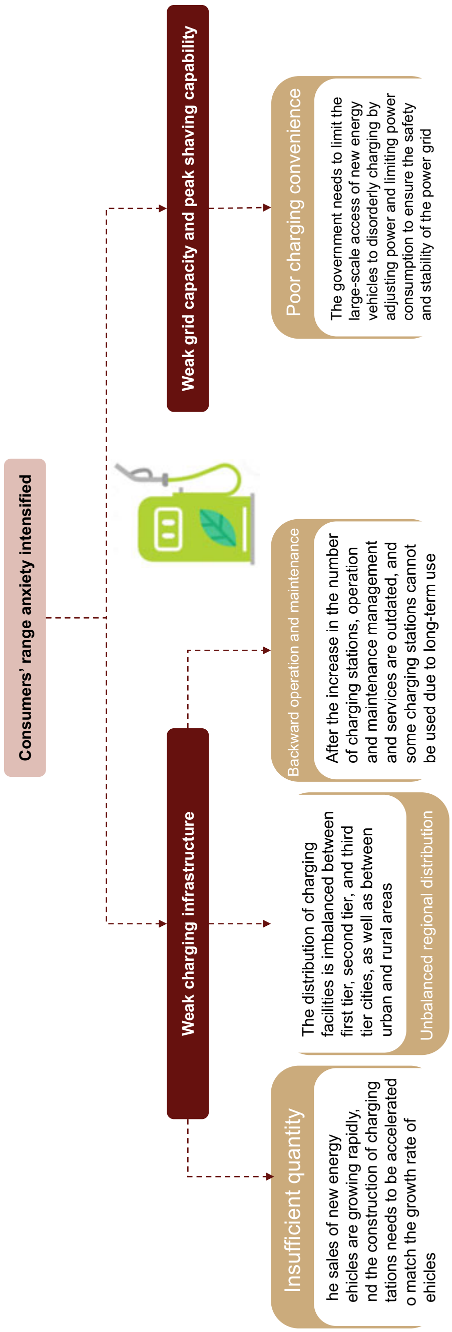

Fig. 13.7 Weak charging infrastructure leads to range anxiety. *Source* CICC Research

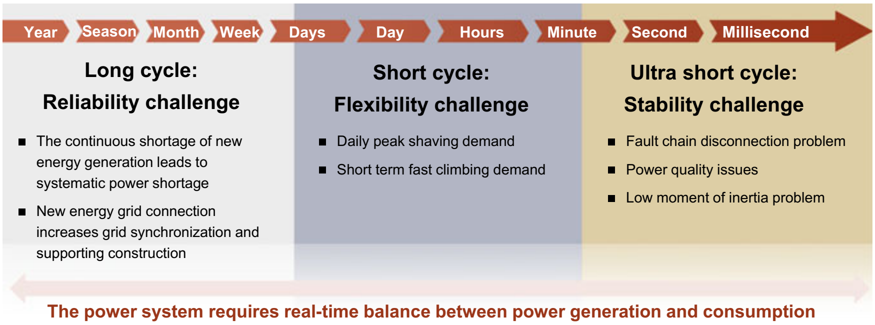

Fig. 13.8 High proportion of new energy in power generation poses challenges to power system operations. *Source* ZHUO Zhenyu, et al., Challenges on Key Technologies and Development of Power Systems with A High Proportion of Renewable Energy (2021), CICC Research

side on the growth of domestic ground-mounted power stations' PV demand has been substantial. **The growth of distributed PV installations is limited by transformer capacity and distribution network carrying capacity. Therefore, capacity expansion for transformers and distribution network transformation in areas with rich wind and solar power is required.** (Fig. 13.8, Fig. 13.9).

13.3.2 Constraints on Product Quality and Return on Investment Need to Be Resolved Through Joint Efforts of Companies and the Market

The safety of LiBs directly affects end-market consumption of AFVs. In the AFV market, vehicle safety is closely related to the safety of LiBs as quality problems or the occurrence of fires or explosions due to external factors such as collisions, charging, high temperature, etc. may lead to LiB-related safety issues. In addition, AFV manufacturers prefer LiBs with high energy density and large-power fast charging functions. This further increases risks of thermal runaways and safety risks.

In the energy storage market, fire accidents related to LiB energy storage stations not only significantly impact consumer safety but also harm the profitability of end-market applications, which in turn affects sales of energy storage batteries to power stations. We expect the government to implement higher safety standards for LiBs and guide companies to address the safety performance of LiBs.

In addition, the relatively high prices of LiBs affect the end-market application economy. In the AFV market, AFVs have green premiums over gasoline-fueled vehicles due to high LiB costs, and the AFV industry's growth still relies on government subsidies. The maintenance costs of LiBs are also high. Integrated die casting technology and intelligent functions both increase maintenance costs when

1. Transformer capacity limitation - Expansion	2. Distribution network impact - Distribution network transformation
▪ Capacity ratio: 80%, 50%, and other transformer capacity restrictions are implemented in various regions ▪ High penetration areas require transformer expansion	▪ The distribution network structure has changed from a radial structure to a multi power supply structure, with changes in the size, flow direction, and distribution characteristics of short-circuit currents ▪ Impact on the distribution network: local voltage exceeding limits, increased voltage fluctuations, frequent reverse flow of power flow, increased short-circuit current, etc ▪ Pressure on absorption/carrying capacity: Industry standards specify that if the reverse transmission of 220KV and above power grids is caused by distributed power sources, the connection of new distributed power projects should be suspended until the carrying capacity of the power grid is effectively improved

Fig. 13.9 Infrastructure constraints for distributed PV development in China. *Source* Technical rule for distributed resources connected to power grid (Q/GDW 1480–2015, released in 2016), Technical guideline for evaluating power grid hosting capacity of distributed resources connected to network (DL/T 2041–2019, released in 2019), CAO Wei, et al., Foreign experience and practical insights on high penetration of distributed PV integration (2022), CICC Research

the vehicle is damaged. In the energy storage market, LiBs are also less competitive than traditional pumped storage and thermal power peak shaving methods. Therefore, we suggest that the industry continue to reduce costs of LiBs via technological upgrades and creation of economies of scale. We also expect government departments to improve the economy of end-market applications and boost end-market demand by providing subsidies and optimizing the profit models of related companies.

13.3.3 Mitigating Land Pressure via Specialized Plans and Key Projects

LiB: The scarcity of high-quality land resources and parking spaces in residential areas affects the construction of charging facilities and indirectly weighs on end-market demand. Public charging facilities: The utilization rate of public charging facilities significantly impacts the return on investment. However, tier-1 cities lack high-quality land resources and face high rents, which may impact return on investment. In addition, public charging facilities are usually built on leased land; therefore, negotiation and cooperation between the local governments and the land use right owners are required.

Private charging facilities: Parking spaces are scarce in some residential areas, with some spaces unsuitable as they lack power sources. In our opinion, the relevant government departments could implement policies to designate more high-quality land resources for the construction of public and private charging facilities. They can also support pilot projects, including adding charging facilities at gas stations, to expand the charging facility network and boost end-market demand for AFVs.

PV: The land utilization rate in the PV segment is low. The land area needed for power generation by solar farms is approximately 15sqm/MWh, larger than that required by nuclear power plants, coal-fired power stations, gas-fired power stations, wind farms, and hydropower plants (0.1, 0.6, 1, 1.3, and 16.9 sqm/MWh). In recent years, the government has tightened land use policies and has strengthened project review and verification procedures. For example, it clearly stipulates that PV projects shall not occupy forest land, farmland, rivers, lakes, and reservoirs.

In addition, land rents in central and eastern China have been rising. In 2021, the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) jointly approved a plan to deploy and accelerate the construction of large-scale wind power photovoltaic bases in deserts and the Gobi Desert and the *Announcement of the List of Pilots for the Development of Roof Distributed Photovoltaics in the Whole Counties (Cities, Districts)*, stipulating land and rooftop PV resources that can support the development of PV projects. With these stipulations, the PV industry can basically meet the wind power PV installation targets set in China's *Action Plan for Carbon Dioxide Peaking Before 2030.*

13.3.4 Increasing Funds via Effective Financing Methods Such as Infrastructure REITs

Charging station and solar farm development and construction are asset-heavy; therefore, the effectiveness of investors' and constructors' financing is crucial. **Market funds such as venture capital (VC) and private equity (PE) are active in supporting LiB and PV manufacturers' technological upgrades and product innovation. In the field of asset-heavy new energy infrastructure operations, we expect infrastructure real estate investment trusts (REITs) to help ease capital pressure on the industry.** We believe that infrastructure REITs are more suitable for the new energy industry given their risk appetites and yield expectations.

On January 30, 2022, *Opinions on Improving the System, Mechanism, and Policy Measures for the Green and Low-Carbon Transformation of Energy,* published by the NDRC, proposes including clean and low-carbon energy projects in infrastructure REITs. On June 1, 2022, in the 14th Five Year Plan for the development of renewable energy sources, the government proposed conducting pilot infrastructure REITs projects for the construction of hydropower plants, wind farms, solar farms, and pumped storage power stations. In 2022, there were about 20 power infrastructure REITs funds to be issued. We expect infrastructure REITs to be a refinancing channel for central and state-owned enterprises in China's electricity sector and help address financial constraints.

13.4 Thoughts and Implications

The efforts of a well-functioning government and an efficient market in China have helped the new energy industry improve industry chain integration and reduce vertical risks. We expect these to further support the relocation of mature capacity, upgrades of advanced technologies, and domestic demand expansion.

Mature capacity transfer: We suggest that companies strengthen cooperation in regional trades and improve the efficiency of their resource utilization in different regions.

Upgrades of advanced capacity in China: We suggest that government departments launch favorable policies to support the industrialization of new technologies. (1) Funds: The government could encourage major market entities to increase investment in new technology by issuing certificates for high-tech companies and launching national research projects. Policy-based financial instruments for new technology developers in the areas of plant construction, equipment purchase, R&D investment, and tax payment are also needed. (2) Employees: The government could provide certain subsidies for skilled technical personnel and inter-disciplinary talent. (3) Patent protection: We suggest that the government improve the intellectual property protection system, shorten the patent review cycle, and reduce the difficulty and cost of protecting rights. The government could also encourage companies to apply for global patents based on their research.

New energy infrastructure: We suggest that the government strengthen the construction and transformation of the power distribution network and optimize the early warning and identification mechanism for grid connection.

Power consumption of ground-mounted PV power stations: We suggest improving power sources, grids, load, and storage, as well as power consumption capacity of centralized PV power stations. We have four suggestions for improving the power consumption capacity of centralized PV power stations. (1) Power source: Companies should step up efforts in R&D, promotion, and application of new energy grid connection technologies; (2) power grid: The construction of electricity transmission channels and the digital transformation of the power grid should be accelerated; (3) load: We propose developing demand response mechanisms on the load side; and (4) energy storage: We expect to see the development of energy storage technologies suitable for multiple application scenarios such as ultra-short-term frequency regulation, short-term peak shaving, and long-term energy storage. We also expect the government to optimize the power market system to increase the return on investment of energy storage projects.

Risks related to system instability caused by the grid connection of new energy: In our opinion, the government could encourage the coordinated development of new energy and energy storage, as well as orderly charging of AFVs.

Chapter 14
China's Auto Industry to Grow From Large to Strong

Abstract The auto industry's competitiveness relies heavily on economies of scale and technological advantages. As it pursues these twin goals, the auto industry has witnessed a century of production model transformations in brands ranging from Ford to Toyota to Tesla.

Deglobalization has posed major challenges to the global auto value and supply chains. The auto value chain is large and complex, relying heavily on global market demand and the integration of technology. As a result, trade frictions, the COVID-19 pandemic, and geopolitical conflicts may cause supply shortages in the global value chain, resulting in short-term production halts. China's auto industry plays a vital role in the global value chain, and in the near term, we think its main goal will be to improve supply chain resilience and maintain scale advantage.

In the long term, the auto industry is undergoing restructuring as disruptive innovation is changing the industry's technological foundation and market landscape. The smart electric vehicle (EV) technology revolution repositions vehicles as intelligent mobile terminals, overcoming traditional automakers' technological barriers in engine and gearbox. In our view, an industrial landscape that is dominated by the traditional giants of the auto industry, including those headquartered in Germany, Japan, the US, and South Korea, is changing. This is creating opportunities for the emergence of China's auto industry on the global stage, but we believe it may also cause overcapacity of outdated production model.

To develop its auto industry in the era of internal combustion engine (ICE) vehicles, China adopted a joint-venture (JV) strategy, attracting core automotive technologies and capabilities with its large market and localizing the production and assembly of overseas models. However, the Chinese auto value chain currently lacks core technologies, in our opinion, making it large but not strong.

In the alternative fuel vehicle (AFV) era, China has boosted domestic demand for AFVs through fiscal and tax policies, and by accelerating technological innovation and market competition in related fields, enabling its AFVs to gain scale and

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technological advantages globally. China now exports AFVs worldwide. In January–September 2022, the country accounted for 62% of global AFV sales volume, with Chinese brands accounting for more than 50% of the global AFV market. In the future, we believe that China may continue to leverage its economies of scale as a large economy and strengthen the technological accumulation of the auto industry by improving the national innovation system. In our opinion, these developments would cement the Chinese auto industry chain's importance in the global market.

Amidst the backdrop of deglobalization, the Chinese auto industry's weaknesses in key technologies are becoming more obvious. To improve China's prowess in cutting edge technologies, the government and the market could work together. The technological transformation of the automobile industry will involve bulk raw materials, basic chemicals, machinery equipment, semiconductors, artificial intelligence (AI), and big data. Auto chips in particular may face a supply shortage. China's automotive semiconductor industry still faces challenges such as the low output of low-end products, mid-range capacity shortages, and a lack of advanced technology in high-end products. Improvements in these areas require advances in domestic technologies.

Keyword Auto value chain · Smart electric vehicles · Technology innovation · Economies of scale

The competitiveness of automobile products has been highly dependent on economies of scale and technological advantages since the dawn of the automobile industry 120 years ago. The auto value chain is large and complex, relying heavily on economies of scale and technological integration supported by globalization. Now, the global auto supply chain is confronted with significant challenges due to security threats, including from trade frictions, the COVID-19 pandemic, natural disasters, and geopolitical conflicts, which are disrupting scale and increasing cost volatility. China's auto supply chain, which is critically important to the global auto supply chain, is also affected.

Meanwhile, the auto value chain is rapidly shifting from traditional ICE vehicles toward smart EVs. The technological and industrial focus of the global auto value chain is changing fundamentally, and a global market dominated by leaders from Germany, Japan, the US, and South Korea is being relegated to history. In our view, it is crucial for China to transform from a large contender that is a major contributor to global auto production and sales to a strong contender whose automakers have a high global market share. We also believe that it is vital for China to seize once-in-a-century opportunities through technological reform and globalization.

14.1 Global Auto Value Chain is Plagued by Supply Chain Issues; China's Auto Industry is Large but Not Strong

14.1.1 The Auto Value Chain Relies on Economies of Scale and Technological Integration in Globalization, and Faces Significant Challenges in the Short Term

Auto manufacturing is at the heart of the auto value chain, with auto parts upstream and the aftermarket downstream. The core components of a vehicle include the powertrain, chassis system, body and interiors & exteriors, electronics & electrical products, general-use parts, and new parts such as smart cockpits and smart driving. Each core module has many sub-components that can be traced back to bulk raw materials, including steel, aluminum, copper, petroleum, and plastic particles. Automotive finance, insurance, leasing, repair and maintenance, automobile accessories, and used cars are all part of the aftermarket.

The auto supply chain has a network structure and a large and complex supporting system, with professional labor distribution and a high degree of globalization. Auto manufacturing is at the heart of the value chain, and original equipment manufacturers (OEMs) have tier-1, tier-2, and tier-3 auto part suppliers. Tier-3 suppliers mainly provide products for tier-2 suppliers, and tier-2 suppliers sell to tier-1 suppliers, which are system integrators. Tier-1 suppliers directly supply products and system solutions for corresponding components to automakers. They have a professional division of labor, and industrial clusters are formed. Tier-1 system integrators have closer ties with automakers and stronger capabilities in synchronous R&D. This allows them to offer value added products and services and remain at the center of the value chain network.

The auto value chain leverages its advantages in the professional division of labor and industrial clusters to benefit from economies of scale and higher efficiency resulting from globalization. However, in recent years, the emergence of *force majeure* risks such as trade frictions, the COVID-19 pandemic, natural disasters, and geopolitical conflicts has negatively impacted the security of the auto value chain.

As shown in Fig. 14.1, the COVID-19 pandemic in 2020 caused a widespread shortage in the auto parts supply chain, forcing most automakers to halt production. Global vehicle output fell for eight consecutive months, with monthly declines at one point reaching nearly 60%. The entire auto supply chain was fragile and out of control. In 2021, COVID-19 resurgence, natural disasters, and other factors caused a severe global automotive chip shortage, which led to a 13% decline in global vehicle output compared to 2019, with a monthly decline of 30% in August 2021. The global auto value chain was significantly shaken by COVID-19 resurgence in Shanghai in 2022, with monthly global vehicle output down 20% at one point.

The auto value chain, which relies heavily on globalization, faces significant challenges in the near term. China, as an important contributor to the global value chain, cannot escape such disruptions and impacts. Its auto value chain is one of

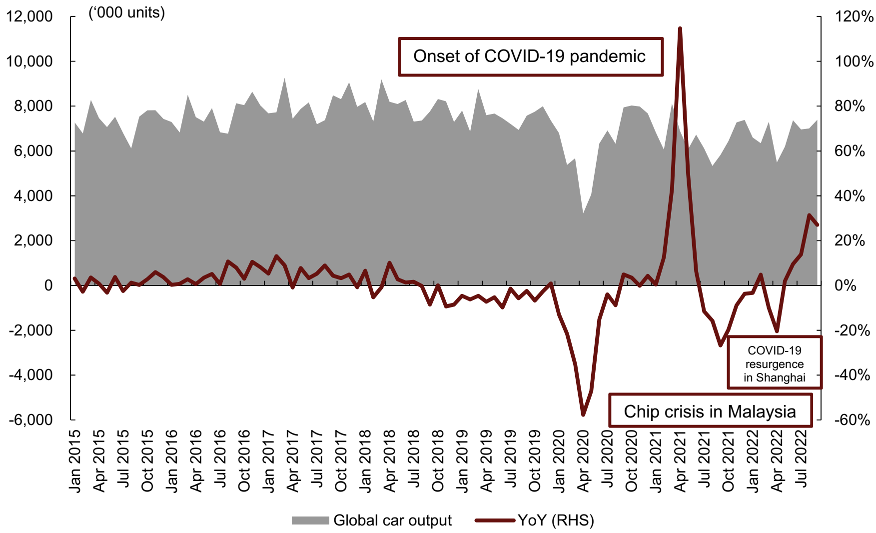


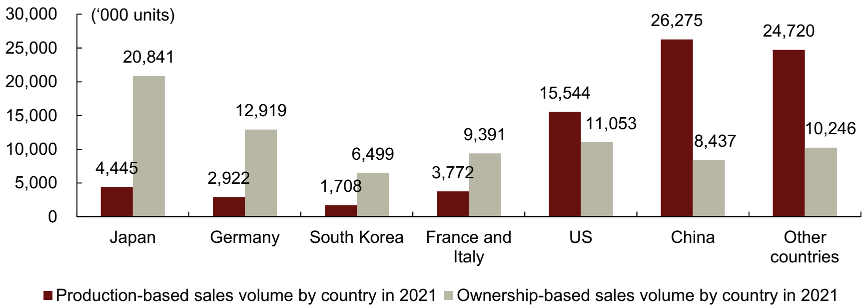
Fig. 14.1 The auto value chain has been hit by supply shortages in recent years. *Source* Marklines, CICC Research

the major industries that have been significantly impacted. Even after the COVID-19 pandemic, some Chinese automakers still face difficulties in producing specific models, delivering orders, or launching new models due to supply and cost issues pertaining to some particular components. As a result, the healthy development of the whole industry has been negatively impacted.

As the core supply chain in China has visible weaknesses, the supply of vehicles and integrated systems remains in danger of supply shortage. The scale advantage of China's auto value chain has been influenced by production suspension, failed order deliveries, and even bankruptcy that once occurred. China's value chain may face the risk of capacity relocation in today's global market if it is unable to complete supply tasks or meet delivery demand over the long term due to shortages in core components and cost pressure.

14.1.2 China's Auto Market is Large but Not Strong; Opportunities and Challenges Coexist in Electrification and Intelligentization

We examine the competitive landscape of the global auto value chain. China's auto industry currently leads in sales as it benefited from and was deeply involved in globalization. In 2021, China sold 26.27 mn vehicles, accounting for 33% of the global total. However, China's auto industry has failed to obtain cutting-edge technologies, making the country a sizeable contender rather than a strong one in the



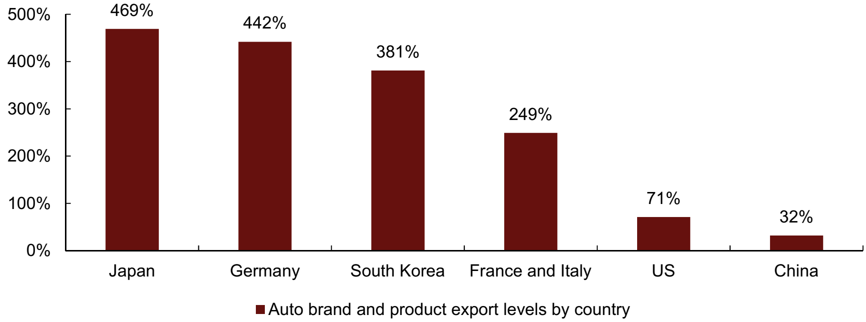


Fig. 14.2 China leads in auto sales volume but lags in product and technology output. *Note* (1) Production-based sales are the sales of vehicles manufactured in a country; ownership-based sales are the sales volume of a specific country's auto brands; (2) Japanese automakers include Toyota, Honda, and Nissan; German automakers are Volkswagen Group, BMW Group, and Daimler Group (now Mercedes-Benz); US automakers include GM and Ford; South Korean automakers are Hyundai and Kia; and Chinese automakers include Great Wall Motor, Geely, Chang'an Auto, GAC Auto, and SAIC Auto's domestic brands, BYD, NIO, Xpeng, and Li Auto; (3) we evaluate a country's auto brand and product exports by calculating the ratio of its auto brand sales to its sales of vehicles produced locally in 2021.*Source* Marklines, CICC Research

global market. Japanese, German, and American brands dominate the global value chain with strong competitiveness and high output in overseas markets. They have a high proportion of overseas capacity and a low proportion of domestic capacity for exports.[1]

In 2021, although China accounted for one-third of global vehicle output and sales, making it the largest producer and consumer, Chinese brands contributed only 45% of domestic output, as shown in Fig. 14.2. In 2021, Chinese automakers produced 8.44 mn units, with a global market share of only 10.6%, a large gap vs. Japan (26.3%), Germany (16.3%), and the US (13.9%).

The economies of scale for specific Chinese automakers fare even worse. As measured by a specific country's ratio of local brand sales volume to total sales

[1] The US output is lower than sales, and US automakers' capacity in Mexico is not included.

of vehicles manufactured locally, Japan (469%), Germany (442%), South Korea (381%), and even France and Italy (249% combined) far outnumbered the 32% in China in 2021. To some extent, China's auto industry only serves as a market for finished products rather than an exporter of core technologies and products, lagging in brand power and technological expertise. We think China still has a long way to go before becoming a strong contender in the global market.

Aside from the visible gap in vehicle manufacturing, China's auto parts market is crowded, but only a few strong brands exist. According to Marklines, China had over 18,000 auto parts suppliers by 2020, as shown in Fig. 14.3, putting it far ahead of other countries. According to Automotive News' Top 100 Global Auto Parts 2021,[2] the Chinese mainland accounted for only seven of the top 100 manufacturers, with average annual revenue of US$3.9bn, significantly lower than the top 100 average. This illustrates that while China has many auto parts companies, most are small. In contrast, Japan, the US, and Germany are far ahead of China regarding the number of companies in the top 100 list and their revenue.

At a micro level, most Chinese firms are tier-2 and tier-3 suppliers at the bottom of the value chain. They are small and have a modest market share. However, most overseas auto parts leaders are multinational system integrators (or tier-1 suppliers) with a presence in multiple product categories, primarily in powertrain components such as engines and gearboxes, chassis system assemblies like steering and brake, automotive electronics, and body and interiors & exteriors. As conglomerates with a global presence, they are at the top of the value chain, with a sizeable revenue and value-added products and services.

However, China has the potential to grow from a large contender to a strong one. The auto value chain is rapidly shifting from traditional ICE cars to smart EVs. The global value chain's technological and industrial focus is changing fundamentally, and a global market dominated by leaders from Germany, Japan, the US, and South Korea is being relegated to history. According to the latest analysis of the auto industry chain and value chain, the global auto market landscape is undergoing major restructuring, and China's value chain is actively participating in and integrating into it. Based on the output value and profitability comparison of the global auto value chain in Fig. 14.4, we may have a more direct understanding of China's status and opportunities.

First, traditional car manufacturing is clearly dominated by leaders from Germany, Japan, the US, and South Korea, each of whose average annual output value exceeds Rmb1trn. Their profitability is high due to strong brand and product positioning. Compared to foreign leaders, Chinese automakers have market shares of 45% in China and 11% globally, supported by China's large car sales volume. They do not lead in product positioning, value for money, or scale, and they lag behind international brands in output value and earnings. The competitive landscape of system integrators (or tier-1 suppliers) engaged in core car manufacturing is very similar. As a result, the traditional auto value chain is dominated by leaders from Germany, Japan, the US, and South Korea. **However, the AFV market**

[2] https://www.autonews.com/data-lists/2021-top-suppliers

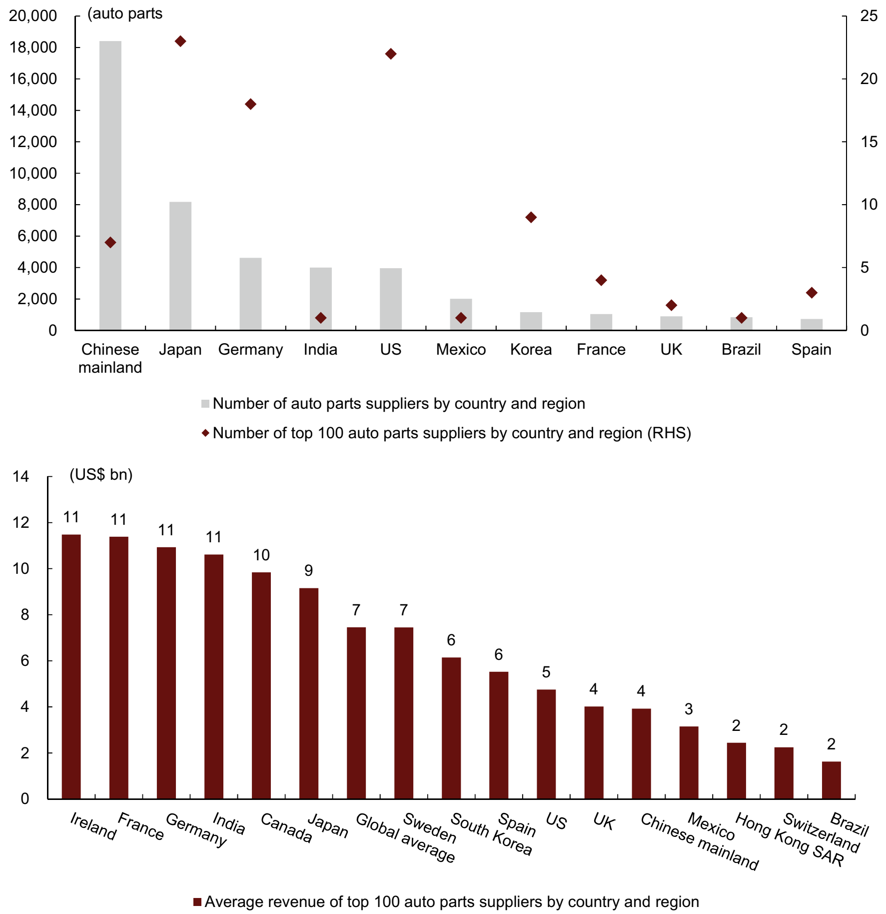


Fig. 14.3 Leading system integrators (tier-1) from Japan, Germany, and the US lead the market with high revenue; China's auto parts market is crowded but with limited strong players. *Source* Marklines, Automotive News, CICC Research

is expanding rapidly, and Chinese and US AFV companies are rising. After a decade of development, Tesla now maintains high output value, earnings, and rapid growth. New Chinese AFV brands such as BYD, NIO, XPeng, and Li Auto are also growing rapidly. Compared to ICE manufacturing, China's AFV manufacturing has taken the global lead in terms of scale. Chinese AFVs have entered the high-end market, and AFV makers' operating quality has significantly improved.

Second, with the rise of Chinese automakers, the country's auto parts value chain is enhanced by the transition to smart EVs. As the rate of localization (or even exports) of China's core parts value chain rises, so do the output value and operating quality of Chinese auto parts companies. By comparing the global operating data of four major auto parts (i.e., seats, interiors, lamps, and automotive

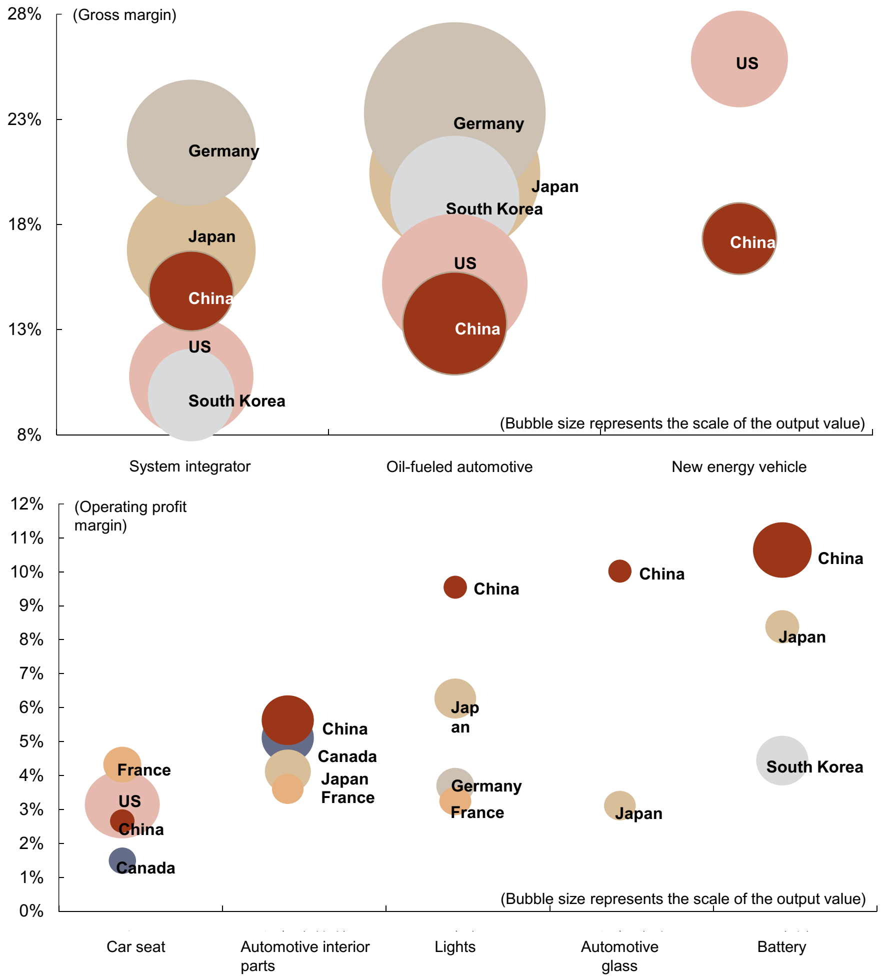


Fig. 14.4 Companies from Germany, Japan, the US, and South Korea dominate the ICE vehicle value chain; China is not competitive in ICE cars, but it is taking the lead in AFVs. *Note* (1) For data comparability and availability, we use operating profit margin to show each economy's value chain positions in the traditional auto parts and AFV parts segments, and GM to show the value chain positions of system integrators (tier-1) and automakers in each country; we use ordinate data and refer to the financial data of related companies in the corresponding segment in 2021; (2) different colored bubbles represent different economies, and the size of the bubbles represents the sum of related companies' operating revenue in each economy in the corresponding segment in 2021, thereby representing the output value of each economy in the corresponding segment; (3) in principle, the economies to which transnational corporations belong are subject to ownership. *Source* Company announcements, Capital IQ, Wind, Marklines, CICC Research

glass, by order of rate of localization from the lowest to the highest), we note that Chinese companies are growing stronger. China has established a leading position in global market share and operating quality for power batteries, which are core components of AFVs. This illustrates that China's auto value chain is at the forefront of this round of smart EV development. At the micro level, China's AFV value chain has gained first-mover advantage in the early stages of the smart EV industry due to scale, technology, and manufacturing advantages.

14.2 Technological Innovation Leads Transformation of Auto Value Chain; New Globalization to Reshape Competitive Landscape

The auto industry faces changes not seen in a century. Vehicle electrification, which began in 2010, broke down the technical barriers of engines and gearboxes that protected traditional automakers. The industry embraced new entrants, brands, and models. The intelligentization of vehicles, which commenced in 2020, has increased the importance of technology in smart EV, and accelerated technological innovation, with iteration shortening the product innovation cycle. Emerging automakers like Tesla have expanded their technology and scale advantages. To compete with Tesla, traditional overseas automakers, and the growing number of tech giants in the industry, China's auto sector faces the challenge of value chain reform led by technological innovation.

Due to government and policy support, Chinese auto brands have gained a leading advantage in scale and technology in the global AFV market. In January–September 2022, China's AFV sales volume totaled 4.36 mn units, accounting for 62% of global AFV sales volume, and Chinese brands successfully sold products overseas, occupying 80% of the AFV market in China and more than 50% globally. In our view, China will likely grow from a large contender in the global auto market into a strong one as its auto value chain accelerates the adaptation to technological changes while ensuring economies of scale and technological advantages.

In particular, facing complex changes in world politics and globalization, the global auto value chain will face new challenges such as the risk of value chain relocation (horizontally) and the lack of core technologies (vertically). The impact will be particularly severe on China's auto value chain, and investors should be wary of the risk of weakening economies of scale and technological constraints.

14.2.1 *Tesla Leads Innovation in Automotive Technology and Changes in Industry Standards*

Studying the history of auto value chain reforms may help us better understand changes in the global auto value chain. The automobile industry has undergone profound changes in demand and technology reforms over the last century, leading to major upheavals in the industry landscape. Automotive products have evolved from niche luxury goods to durable household goods, personalized consumer goods, and mobile smart terminals (a new definition for the latest iteration of vehicles).

Meanwhile, the auto value chain and industry landscape have undergone four major stages of change: (1) Small batch and all handmade production in the early days; (2) Ford's vertically integrated mass production (assembly line), which supports mass marketing; (3) Toyota's production system, which features labor division and outsourcing (lean production) and helps reduce costs and achieve customization; and (4) the smart EV revolution led by Tesla, with the firm introducing renewable energy and AI technologies to the automotive industry, adopting a vertically integrated industry chain, and redefining vehicles as smart mobile terminals.

Cars were produced in small batches after they first appeared in 1885 as they were handmade and could not be mass produced at low cost and with high quality. As a result, cars could only be a luxury for the rich.

In 1913, Henry Ford, founder of the Ford Motor Company, began mass-producing standardized models on assembly lines. Ford's production efficiency increased from 100 cars per year in 1906 to an average of one car every 10 s in 1925, dragging down the ASP. Ford's Model T cost only US$360 in 1916.[3] Automobiles gradually became mass consumer goods as a result. Ford's production line covered the entire supply chain from raw material procurement to product design, parts manufacturing, finished product assembly, and final product sales. The company has established a large, comprehensive, and standardized vertically integrated vehicle-parts production system that gives full play to the automobile industry chain's advantages of standardization, large scale, and low cost.

Since the 1980s, the Toyota production system has aimed to eliminate waste and reduce costs, focusing on "just-in-time" production and automation to improve operations. The Toyota production system shortens the length of the value chain in which the firm is directly involved, focuses on vehicle assembly, and fully leverages its advantages in vehicle production scale.[4] It also outsources parts and component businesses to third-parties to reduce internal organizational costs and improve operational efficiency. However, the firm controls the R&D, design, and manufacturing

[3] WANG Pusheng, et al. "Evolution and Characteristics of Global Production Models in the Perspective of Industrial Philosophy—From Fordism and Toyotism to Wintelism." *Studies in Philosophy of Science and Technology* 25.3(2008):96-101.

[4] Pavitt, Keith. "Sectoral patterns of technical change: towards a taxonomy and a theory." *Research policy* 13.6 (1984): 343-373. WANG Pusheng et al. "Evolution and Characteristics of Global Production Models in the Perspective of Industrial Philosophy—From Fordism and Toyotism to Wintelism." *Studies in Philosophy of Science and Technology* 25.3(2008):96-101.

of upstream components through cross-shareholding, reducing external transaction costs and eventually building its own supply chain systems for components and raw materials, thereby maintaining a dominant position in the value chain and economies of scale.

As the automobile industry entered the twenty-first century, Tesla took the lead in the vertically integrated new smart EV value chain by meeting user needs with an industrial ecosystem that is able to respond quickly to market changes and is super-connected and efficient. It independently develops and manufactures a full range of EV software and hardware and expands to upstream components. Such a vertically integrated model has disrupted the Toyota model's horizontal professional division of labor and outsourcing. Tesla's model is becoming a new industrial standard.

Tesla's vertically integrated model is a product of the times and technological advances. (1) Technological reform triggers disruptive innovation, just as regulations to reduce emissions in the ICE vehicle value chain resulted in disruptive innovation in the form of smart EV technology. As the old auto value chain lacked the capacity and impetus to comply when the reforms were first introduced, emerging automakers such as Tesla had to develop and produce products on their own using new and disruptive technologies.

(2) Technological advancement (the process in which the design of the product is improved through repeated trial and review) is generally fast paced when a technology is first introduced, and the product iteration cycle is short. As technological innovation determines the limits of product power, emerging automakers such as Tesla have increased R&D efforts to maintain their leading positions in product technology.

(3) Competition for dominance in the value chain: Under the Toyota production system, OEMs have a shorter value chain and only have the technical reserves for manufacturing vehicles rather than specific components. In our opinion, Toyota's smart EV value chain is poorly constructed. In the era of ICE vehicles, system integrators, or tier-1 suppliers, had strong bargaining power. The technological transformation of smart EVs has created significant demand for the large-scale production of new or higher-value components, resulting in vacuums in the upstream and downstream. Plugging these gaps requires the reconstruction of the auto value chain. Emerging automakers, represented by Tesla, expect to dominate the industry chain in the future.

(4) Digitalization and software applications allow Tesla to achieve high production and operating efficiency in vertical integration and independent R&D within the system, bearing lower internal communication and organizational costs compared to costs relating to transactions with external parties.

In our opinion, these are important reasons for Tesla to have adopted a vertically integrated model which provided the firm with an industry-leading position based on the new-generation industrial standard. However, Tesla's success also relies on industrial innovation and technology and fully exploiting the scale advantage of China's auto value chain.

Tesla CEO, Elon Musk, uses the first principles thinking model (questioning established assumptions about an issue before working on a new solution) to challenge the traditional auto industry's development model and standards. He proposed a development strategy of first producing sports cars and using the profits to produce luxury cars, then using the earnings from the latter to produce cars with potentially high sales volumes. He has since proposed an ecosystem strategy based on AI and cross-sector integration of EV, photovoltaic (PV) energy storage, and robots. Tesla has a clear corporate mission, in our view, as well as a well-defined industrial strategy and development path.

In our opinion, the disruptive innovation introduced by Tesla dealt a blow to the ICE value chain while introducing smart EV technology and transforming the auto manufacturing value chain. In electrification, to achieve high-dimensional competitive advantages in power systems, Tesla has built a three-part electric system (the power battery, drive motor, and electronic control system) with leading performance and an advanced green energy charging network (including the SolarCity and Supercharger projects). In intelligence transformation, the firm has also integrated software and hardware and built a path to achieve autonomous driving using computer vision, AI, and chips. It creates a closed-loop training system featuring massive data collection, automatic labeling, and simulation capabilities.

The company plans to leverage its Dojo supercomputing system (the finished Dojo Pod contains 3,000 D1 self-developed training chips and has a total computing power of 1.1EFLOPS, ranking No.5 on the global supercomputing list), Optimus humanoid robot, and Robotaxi to expand AI application scenarios, making it the technological base for applications in the transportation and energy fields and achieving multi-dimensional cross-sector integration and innovation. The technological barriers for smart EVs that Tesla is building are becoming a barrier that competitors and traditional auto value chains may find difficult to overcome in the near term.

Tesla also innovates in all areas, including R&D, design, manufacturing, and sales services. It has become an absolute leader in the smart EV value chain from which everyone learns thanks to its: (1) Innovative technologies such as integrated die-casting, 4680 battery, and cell-to-chassis (CTC); (2) logistics and material-centered gigafactory; (3) product strategy for blockbuster products; and 4) new marketing approach combining offline experience stores and direct sales on its official website.

Tesla is an innovator and an integrator in the value chain. The high efficiency, low cost, and industrial cluster advantages of China's auto value chain and the independently built Shanghai factory in China have helped Tesla achieve sales ramp-up and rapid scale expansion. The advantages of "Made in China" regarding speed and cost have been fully reflected.

Tesla suffered a delivery crisis over 2014–2020 due to constraints from battery production capacity and delays in production line transformation at its US factory. Since then, Elon Musk has visited China seven times to push forward the construction of the company's Shanghai factory and the localization of its supply chain. Construction of the Shanghai factory began in January 2019, and was completed earlier than expected in December 2019, with the factory initially delivering China-made Model 3 vehicles. Tesla completed Model Y localization in China in early 2021. China's AFV value chain boomed as the Model 3 and Model Y vehicles became popular. China has since become Tesla's largest single sales market and manufacturing base.

In short, the automobile value chain's century-old pattern is being visibly restructured. The old barriers are collapsing due to the tremendous changes in product definition, the focus on technology, and the core of the value chain, while new barriers are quietly being built. Inevitably, smart EVs will see faster technological advancements, shorter product cycles, and fierce competition, in our view. We examine the possible policy measures for China's auto industry and value chain, and changes in industrial standard in the face of innovation leaders such as Tesla.

14.2.2 Underperformance of "Market-For-Technology" Strategy; Adapting to Technological Changes; China's Smart EVs May Overtake Others

China has failed to become a strong contender in the ICE era, but a new era of smart Evs has arrived. In our view, how China's auto value chain adapts to electrification and intelligence transformation and doing so as rapidly as possible while ensuring economies of scale and technological leadership in smart EVs is the key to China's transformation from a major player to a strong one and for China's auto value chain to seize opportunities and take the lead in the market. However, due to rapid technological disruption and innovation, we are concerned about the potential overcapacity of ICE cars and parts in China's auto value chain.

First, we review the history of China's auto industry and the milestones, status quo, and outlook of the country's auto value chain:

1. From the 1980s to 2000, China opened up to the outside world and introduced the JV model, hoping to attract core automotive technologies and capabilities with its large market and localize the production and assembly of overseas models. As the localization rate of JV automakers increased, China gradually improved its auto parts supply, resulting in the birth of non-state-owned domestic automakers like Geely and Great Wall Motor.
2. Between 2000 and 2014, China's car demand grew rapidly as personal incomes increased and the government continued to support automobile consumption. China's car sales increased from less than 2 mn to 20 mn units. Both JV brands and Chinese brands thrived amid substantial industry growth. JV automakers' introduction of advanced products and new technologies stimulated market demand and pushed forward the development of China's auto parts supporting system. From the 1980s to the end of the twentieth century, the localization rate of JV automakers' auto parts increased from less than 10% to more than 80%.[5] Some strong parts suppliers emerged in subsegments, gradually forming large and complete industrial clusters in China, laying the groundwork for building

[5] China Industry Statistical Yearbook. PENG Bo. *Evolution and Performance of China's Automobile Industry Innovation System.* Diss. Tsinghua University, 2012. [Chinese only].

advantages in low cost, high efficiency, strong agglomerative effect, and abundant technical personnel.

3. Since 2014, China has pursued the strategy of developing AFV as the only way to become a strong player in the auto industry.[6] Although China's auto sales volume peaked in 2017, the industry was dominated by electrification and intelligence transformation and the rise of Chinese brands. China's continued AFV incentive policies and stronger opening-up policies (e.g., the introduction of Tesla and the removal of shareholding restrictions on foreign investment in the auto industry) are improving the country's AFV supply chain and supply of high-quality AFV models, driving strong AFV sales growth in a healthy way (no longer relying on subsidies). China's AFV sales volume totaled 4.36 mn units over January–September 2022, accounting for 62% of the global AFV sales volume.[7] The AFV market share of Chinese brands was as high as 80% in the Chinese market and more than 50% in the global AFV market. China is exporting AFVs overseas. Due to the rapid increase in AFV penetration, Chinese brands' market share in China rose to 48% in 9M22 from 34% in 2014.[8]

In short, although China's automobile industry was established much later than developed countries, after four decades of development, it has formed an automobile value chain featuring low cost, high efficiency, strong agglomerative effect, and abundant technical personnel.

China's auto value chain is following Tesla's pace of innovation and creating differentiated advantages. Taking Tesla's lead, Chinese automakers are accumulating electrification and intelligence technologies. They have launched integrated electrical drive systems, improved the performance of power batteries, and improved their charging and swapping networks in terms of EVs. Regarding intelligence transformation, they have upgraded driver assistance systems and achieved redundancy of front-mounted chips with large computing power and high-level sensors such as LiDAR. Furthermore, they are adopting integrated die-casting technology and reaping the advantages of the direct-operation model in distribution channels. Apart from learning from their foreign counterparts, Chinese automakers are also creating differentiated advantages, maintaining scale advantages in sales volume and market leadership in niche markets of different price ranges by leveraging their brand and product positioning, strong EV technology reserves, rapid model iteration, and innovative breakthroughs in intelligence transformation.

Chinese automakers are adapting to the industrial revolution and vertically expanding along the value chain. BYD is the world's only company capable of mass-producing both power batteries and EVs. It has mastered core electrification technologies such as power semiconductors, dual-core batteries, and motor and electronic control technologies, allowing it to integrate the entire EV value chain. Other Chinese automakers have increased their efforts to expand in EV batteries via equity investment, joint ventures, strategic cooperation, and independent R&D.

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[6] http://www.xinhuanet.com/politics/2014-05/24/c_1110843312.htm [Chinese only].

[7] Source: Marklines.

[8] Source: Marklines.

Regarding intelligence transformation, Chinese automakers are pushing forward the R&D of autonomous driving and expanding the industry ecosystem to upstream electronic and electrical architecture, chips, algorithms, and other components. For example, NIO, XPeng, and Li Auto upgraded their centralized domain control architecture, and traditional Chinese automakers have corresponding plans for upgrades to improve the user experience of intelligent automotive products. Furthermore, Chinese automakers are increasing their presence in autonomous driving through outsourcing, strategic investment, cooperative development, and full-stack independent R&D. Domestic automakers, however, are lagging in vertical expansion in the smart car value chain when compared to Tesla's self-developed autonomous driving systems and chips.

We note that China's auto value chain is favored by Chinese consumers, especially young car buyers, due to its flexible industrial architecture, strong insights into consumer demand, and rapid product upgrades. We expect China to adapt to technology reform as soon as possible, ensure economies of scale and technological leadership in smart EVs, and grow from a large contender in the global auto market to a strong one.

14.2.3 The Global Automobile Industry Faces Horizontal Risks of Supply Chain Shortage and Value Chain Relocation

The auto value chain is highly globalized, and in recent years, supply security has been impacted by trade frictions, the COVID-19 pandemic, natural disasters, and geopolitical conflicts. The supply shortages of some auto parts have disrupted the global value chain's scale, caused cost fluctuations, and increased the risk of production suspension and reduction. Such conditions are plaguing the global auto value chain and pushing automakers to adjust their industry chain expansion and supply chain strategies. How to effectively solve the supply chain shortage and improve the horizontal security of the value chain has become an urgent focus for the auto industry. Please see Fig. 14.1 for details.

As a major player in the auto value chain, China currently confronts risks related to value chain relocation and supply chain shortages, and it is necessary to be wary of losing economies of scale in the near future. Some overseas multinational automakers may shift orders away from Chinese suppliers to ensure supply chain security, resulting in the relocation of the auto value chain to foreign countries. Domestically, Chinese automakers rely heavily on upstream core components such as core equipment, semiconductors, and basic chemicals supplied by overseas companies.

However, we propose four reasons why it is unlikely that the auto value chain will retreat from China **in the near term**.

1. China accounts for one-third of global auto production and sales, and its biggest competitive advantage is its large demand. Multinational companies' business in China focuses mainly on serving local clients.
2. Auto parts suppliers have high stickiness levels due to stringent requirements for automotive-grade products, and have high stickiness levels in the supply chain, while automakers are more likely to reduce risks by diversifying suppliers rather than moving away from a specific country.
3. The supply chain of labor-cost-driven components is more likely to be replaced and relocated to countries and regions with lower labor costs, such as India, Southeast Asia, and Mexico, while China's advantages in transportation cost, technology, and manufacturing process-driven components are less likely to be substituted.
4. Insufficient industrial clusters in other regions. China's auto parts industry clusters still enjoy clear economies of scale, while other regions and countries such as Southeast Asia and India export less auto parts and components, which means they are not yet able to handle large amounts of orders that may be shifted from China.

China's auto supply chain should be well prepared to ensure long-term supply chain security and push forward global expansion. The country is building a secure supply chain by regionalizing and decentralizing, stockpiling inventory, and shortening supply distances. Domestic automakers should accelerate the implementation of the globalization strategy, in our view, introducing products and technologies to overseas markets.

14.2.4 Vertical Risk Exposure to Key Technologies in the Automobile Value Chain

Automobiles, as high-value end-market goods, are influenced by upstream and midstream industries such as bulk raw materials, basic chemicals, machinery and equipment, semiconductors, AI, and big data. We expect vehicles to become smart mobile terminals in the wake of technology reforms. Following technological upgrades, global automakers may suffer from production halts and shutdowns due to core component shortages and supply disruptions. China now has shortcomings in vehicle intelligence, including chassis-by-wire, auto chips, and AI algorithms for autonomous driving. It is necessary to pay close attention to these issues, in our view.

Reliance on imports and low localization rates are major issues for automotive semiconductors. ICE cars are mechanical products, with chips accounting for a low proportion of total value. As AFV's electric, smart, and integrated functions increase, so will their reliance on chip usage and performance. There are three types of automotive semiconductors. (1) Processing technologies for power semiconductors, microcontroller units (MCU), and sensors are mature, and the growth in market share of Chinese suppliers is accelerating. (2) System-on-a-chip (SoC) technologies are rapidly evolving. Domestic firms have made breakthroughs in low-performance, low-process products but lag far behind overseas peers. (3) AI training chips for autonomous driving, with high computing power and processes, are dominated by foreign companies as Chinese companies have not developed the technology.

14.3 Thoughts and Implications: Guiding the Market to Ensure Domestic Demand; Fully Supporting Technological Breakthroughs

Automobile products, as shown in Fig. 14.5, have consumer goods characteristics as well as high manufacturing technology requirements and a large and complex value chain. From a macro perspective, competition in the auto value chain relies heavily on economies of scale and technological strengths. Therefore, we draw some assumptions and implications by constructing a **scale and technology-based competitiveness model for China's auto industry**:

1. Technological factors: The core technological barrier of ICE cars has almost disappeared, and smart EVs have become the main direction for future automotive technology.
2. Regulatory factors: The industry needs policies to guide and encourage breakthroughs in core technologies and full competition in the open market to ensure economies of scale in China's auto value chain.

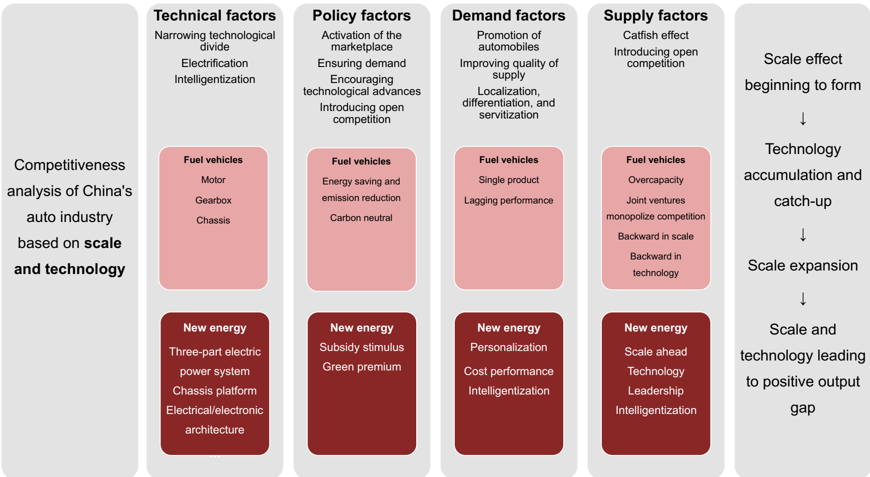

Fig. 14.5 Competitiveness analysis of China's auto industry based on scale and technology. *Source* CICC Research

3. On the demand side, stakeholders in the industry should provide infrastructure and supporting services for automobile consumption to meet the needs of automobile popularization. Smart EVs far outperform ICE vehicles in terms of consumer experience and technology empowerment. Only by ensuring the supply of high-quality advanced vehicles from automakers can the industry create long-term stable demand, achieving economies of scale in a large market.
4. Regarding supply factors, the smart EV trend cannot be halted, and the catfish effect represented by Tesla is accelerating industry disruption and innovation. In open competition, more new entrants, technologies, and skilled workers may create a positive cycle in which business scale and technology drive each other's development.

Chapter 15
Pharmaceuticals: Chinese Companies to Increase Efforts in Innovation and Expand to Higher-Added-Value Processes

Abstract **Given China's aging population, the ability of the country's pharmaceutical companies to provide high-quality products has become a critical issue.** As the world's second-largest individual pharmaceutical market, China exhibits a competitive landscape in the pharmaceutical industry that still has room for further development compared to the US, the leading market in the world. In China, the contradiction between rising medical demand and a lack of innovation in pharmaceutical products may be one of the core issues affecting people's livelihoods. We believe it is critical for the government and public sector to improve the innovation capabilities of the pharmaceutical industry and to build value chains locally, expanding to processes with higher added value on the value chain and narrowing the gap with the world's leading market. In this chapter, we analyze the Chinese pharmaceutical industry's upgrading trend from the perspective of the pharmaceutical supply chain system and ecosystem innovation.

Pharmaceutical supply chain systems are classified based on the R&D process. Pharmaceutical R&D has a long cycle. It is relatively independent as it has to meet various types of needs. The economies of scale achieved from the division of labor in the R&D process can substantially reduce R&D costs. Therefore, core pharmaceutical supply chain systems are classified according to the process from R&D to production and marketing. Meanwhile, hardware such as equipment and reagents are used in R&D and production, and they constitute a secondary supply chain system.

Pharmaceutical R&D is an ecosystem in which the software is more important than the hardware. Given that every individual has personalized pharmaceutical needs, allocating resources to pursue breakthroughs in a single category cannot improve the competitiveness of the whole industry. Therefore, a well-balanced and evolving ecosystem is the key to competitiveness. The ecosystem includes systems for regulation, scientific research, payments, as well as the capital market, among other factors. Good products can only be continuously incubated to meet patient needs by achieving a dynamic balance of these factors and through market-oriented

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means. These "soft factors" are the key to competition between countries. Although hardware factors such as medical equipment and reagents are important, most weak hardware processes can be solved or replaced through R&D. As a result, software is more important than hardware in pharmaceutical R&D.

A new national system to strengthen the software of the pharmaceutical ecosystem; Chinese companies to increase their presence in higher-added-value processes. Since 2015, China has implemented a comprehensive reform of the pharmaceutical industry, aiming to improve the ecosystem's competitiveness and to encourage domestic companies to expand into higher value-added processes. **Regulation:** R&D efficiency of new drugs has improved notably since the drug review reform, and integrating its drug review system with global standards has accelerated the integration of China's R&D ecosystem. **Market-based payment:** The National Healthcare Security Administration (NHSA) is accelerating the exit of inefficient products so that more resources are channeled to high-quality products. **Capital market:** The introduction of Chapter 18A (The Stock Exchange of Hong Kong Limited introduced Chapter 18A to permit the listing of biotech companies that do not meet any Main Board financial eligibility tests.) and the establishment of the SSE STAR Market has made financing more convenient for innovative companies. The primary market has become more active in investing in the pharmaceutical industry, attracting a large amount of investment for innovative product incubation. Comprehensive reform has improved the pharmaceutical ecosystem, making it more competitive. We expect the domestic pharmaceutical industry to gradually shift from R&D outsourcing toward high-value-added innovative products.

Keywords Pharmaceuticals · CRO · CDMO · Biotech innovation · Innovative drugs

Pharmaceutical innovation is an important part of the upgrading of high-end manufacturing industries, and there has been increasing discussion in recent years about what constitutes an appropriate development model. The COVID-19 pandemic has put countries' healthcare systems and pharmaceutical industries to the test. Only a few countries and regions developed drugs and vaccines for COVID-19. Though designed for cancer treatment, mRNA technology was first used in vaccines. These types of use cases raise the question of what type of pharmaceutical system can meet increasingly personalized or urgent medical needs.

Medicines, primarily non-standard products designed for different diseases, typically have several rounds of iteration, and utilizing public resources to seek breakthroughs in a single direction is usually inefficient. We believe new technologies and competitive products can be cultivated only by building a market-oriented ecosystem driven by end-market demand. This effort requires supportive policies in fields such as regulation, payment, investment, and financing to create a virtuous cycle, which can then form a new national system. Such complexity explains why only a few countries and regions can build a competitive system.

This chapter reviews the pharmaceutical supply chain system and ecosystem, and discusses the necessity of and core directions in developing a new national pharmaceutical system.

15.1 R&D is the Core of the Pharmaceutical Supply Chain System

15.1.1 Pharmaceutical R&D: A Progressive Screening Process

Pharmaceutical R&D is a one-in-a-million progressive screening process. R&D of innovative drugs must go through several processes, including project launches, drug discovery, preclinical and clinical trials, and marketing. Drug development is often characterized by high investment, a long cycle, and a low rate of success due to the complicated R&D process and strict approval standards. For every 10,000 compound candidates, there might be only one drug that makes it through the R&D process and enters the market (Fig. 15.1).

According to scenario and type of asset used at different stages, new drug R&D can be divided into laboratory, hospital, and factory stages.

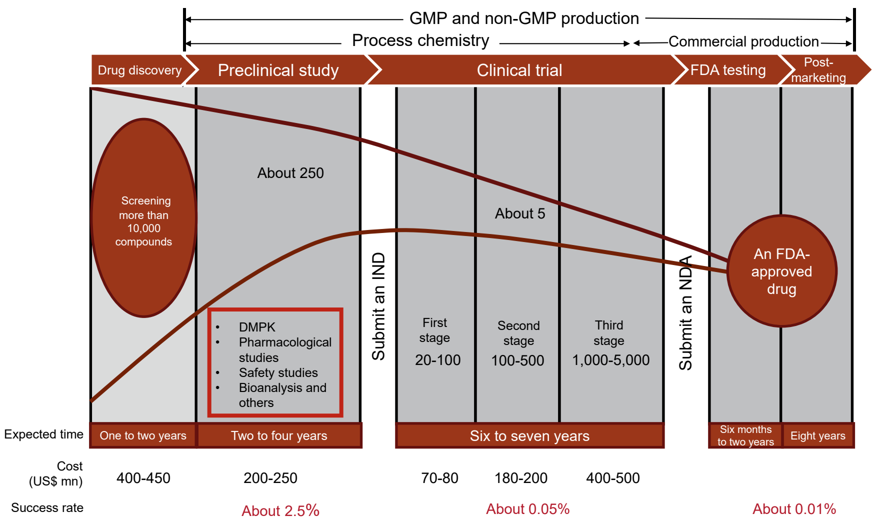

Fig. 15.1 A typical timeline for new drug development. *Note* GMP = good manufacturing practices; DMPK = drug metabolism and pharmacokinetics; IND = investigational new drug; NDA = new drug application; FDA is the US Food and Drug Administration. *Source* Frost & Sullivan, CICC Research

Laboratories: Preclinical development; skilled worker-intensive. In the early stages of drug discovery and preclinical laboratory in innovative drug R&D, laboratories are the primary R&D scenario. Laboratory R&D consists primarily of repeated trials in three dimensions: Drug safety (toxicological studies), efficacy (pharmacological studies), and chemical manufacturing and control (CMC, pharmacological studies or druggability). New business projects such as drug discovery and optimization have emerged to help innovative drug companies. Only one drug out of 5,000–10,000 compound candidates may reach the market. The size of laboratories and the number of laboratory staff are the primary indicators of production capacity, and laboratories are skilled-worker intensive.

Hospitals: Clinical trials are resource and labor-intensive. Clinical trials are the continuation of preclinical drug R&D, in which systematic studies are conducted on patients and healthy volunteers. Clinical trials aim to confirm or discover the pharmacological and pharmacodynamic effects, adverse reactions, absorption, distribution, metabolism, and excretion of the experimental drug to determine its efficacy and safety. Clinical trials are generally divided into phases I, II, III, and IV. They have high barriers to entry and require high-quality clinical resources. The core sub-businesses of clinical trials, including site management, clinical monitoring, data management, and statistical analysis, are closely related to the project execution team. The number of personnel is a primary indicator of production capacity.

Factories: Marketing applications and commercial production are capital-intensive. Factory production, which is asset-heavy and capital-intensive, mainly refers to the production and packaging of clinical drugs, intermediates, active pharmaceutical ingredients (APIs), and preparations. Pharmaceutical equipment and related consumables used in process and formula development, such as small molecule and macromolecule reactors, are involved in production.

A pharmaceutical innovation and R&D system comprises pharmaceutical R&D, the hardware supply chain, and the software ecosystem. The hardware supply chain includes scientific research equipment and reagents (upstream of laboratories), patient recruitment (upstream of hospital clinical trials), and pharmaceutical equipment and consumables (upstream of manufacturing). The software ecosystem includes education-related basic science, regulatory systems for approval and review, a capital market that could help accelerate incubation, and end-market payment systems. (Fig. 15.2).

15.1.2 The Hardware of the Pharmaceutical R&D Supply Chain System: Configuration of the R&D Process

Scientific research equipment is upstream of laboratories. Life science research equipment covers several sub-categories, including sequencing equipment for genetic

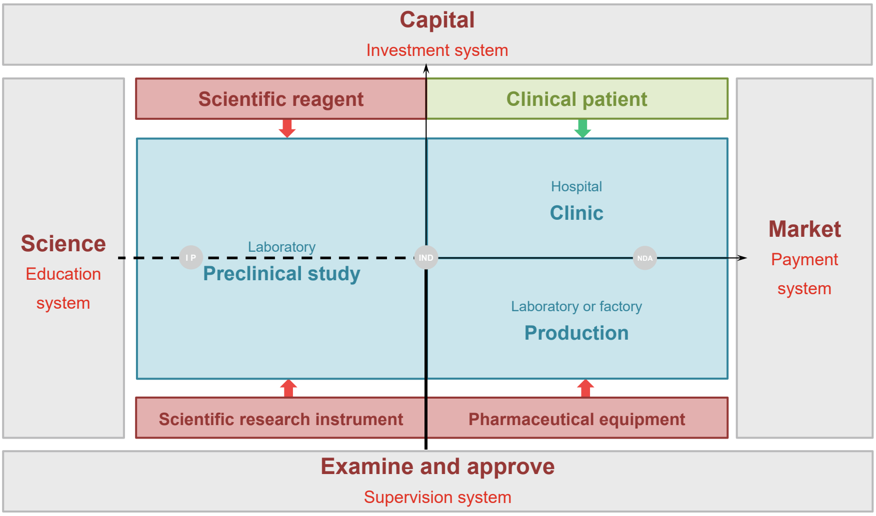

Fig. 15.2 Value chain and ecosystem of pharmaceutical R&D. *Source* CICC Research

inheritance, biochemical analysis equipment, mass spectrometry equipment, chromatography equipment, and analytical equipment for other specific indicators. **Scientific research reagents are upstream of laboratories.** They include both chemical reagents and biological reagents. The chemical reagents have reached a relatively mature stage of development, and in recent years, biological reagents have developed rapidly thanks to the boom in macromolecular biologic drugs, medical testing, and cell and gene therapy. These biological reagents are also new upstream raw materials with high barriers to entry.

Clinical patient recruitment is upstream of clinical trials. Clinical trials in Phases I to III typically require thousands of patients. Clinical time is made up of clinical enrollment time and experimental execution time. As the experimental execution time is relatively fixed, clinical enrollment time becomes an important variable in overall clinical time. China has a large population, with many disease types and cases, and abundant clinical research resources.

Upstream of factories are equipment and consumables for large manufacturing industries. Pharmaceutical equipment includes machinery equipment and packaging materials used in pharmaceutical production, testing, packaging, and other manufacturing procedures. The pharmaceutical equipment industry is in the upstream, and an important component of the pharmaceutical industry. The four components of the biological drug preparation process can be divided into drug screening and cell strain construction, cell culture, downstream purification, and preparation canning.

15.1.3 The Software of the Pharmaceutical R&D Ecosystem: Scientific Breakthroughs, Regulatory Guidance, Capital Acceleration, Market Feedback

End-user demand is personalized and fragmented, and concentrated R&D tends to solve problems with a limited scope. Due to the diversity of the human genome, different patients will have different drug responses. For example, a single antitumor drug might only be effective for 10–30% of patients. Therefore, it is necessary to provide personalized solutions based on the characteristics and conditions of patients, including diagnosis, drugs, treatment plans, and rehabilitation. In this context, it is crucial to build an ecosystem that can evolve sustainably and incubate companies that innovate continuously.

Scientific research (education system): Target discovery and addressing curative mechanism. Innovations at the beginning of the drug development process such as mechanism research and target discovery need to be driven by high-quality basic research in academia. Transforming basic research findings into clinical research requires systematic translational science and support from skilled workers. The support of pharmaceutical companies can help maximize the clinical and commercial value of cutting-edge discoveries. Basic disciplines such as life sciences and translational medicine's exploration of the relationship between pathogenesis and potential targets provides the foundation and guidance for R&D of new drugs. The laboratories of scientific research institutions are the primary source of drug innovation.

Regulation (approval system): Regulations guide the direction of R&D. The allocation of more high-quality resources in evaluation and approval of innovative drugs urgently needed for clinical trials requires regulatory support and guidance. Pharmaceutical development is closely related to regulatory science. Functional departments are involved in registration management, production quality, pricing, circulation, and intellectual property to create a favorable institutional environment for a series of changes in concepts and innovation of mechanisms. Optimizing the supply of approval and review resources, and thus reducing institutional and regulatory costs, can help remove barriers to launching new drugs. The guiding role of regulators is also important in strengthening industry standardization, including raising quality requirements for the design of clinical studies for new drugs. In our view, regulation plays a unique role in allocating resources and setting directions for improving the innovation ecosystem and optimizing the industrial structure of China's pharmaceutical industry.

Capital (investment system): Accelerating progress in drug R&D and solving funding issues. Government investment is needed to strengthen basic scientific research capability, and social investment is needed in the risk-sharing of cutting-edge innovation commercialization. As the basic scientific research system plays a supporting role but is unlikely to generate high returns in the short term, the government is the primary source of investment. Meanwhile, investing in innovative drug R&D is characterized by high risk, high investment, and a long cycle. It is difficult for individual researchers to raise funds for sustained R&D and to bear R&D

risks. Therefore, early-stage venture capital is crucial to the biotechnology industry's development, and securitization financing is required to diversify risks. High pricing encourages investment in high-risk projects, while low pricing stimulates investment in low-risk projects.

Market (payment system): An R&D process with high returns and risks. A bargaining and payment system that favors innovation outcomes, we think, could encourage pharmaceutical companies to invest in cutting-edge fields. Best in class (BIC) and first in class (FIC) products usually have high value and higher R&D risks, placing higher requirements on product commercialization expectations. As the commercialization of new drugs typically begins in the domestic market, we think improving the payment system's capacity for fund raising, clarifying its guidance of clinical value, and paying innovation premiums for high-risk innovations can encourage pharmaceutical companies to invest in the cutting edge.

15.2 China Enters the Global Outsourcing Business; the Hardware Supply Chain is Gradually Replacing Imports

15.2.1 R&D Process Benefits From Outsourcing; China Has an Engineer Dividend

Outsourcing accelerates pharmaceutical R&D. R&D outsourcing undertaken by a contract X organization (CXO) includes service-focused contract research organizations (CRO) and manufacturing-focused contract manufacture organizations (CMO). CRO and CMO are customized outsourcing systems that provide innovative drug developers with research support and production and supply services, which can substantially improve R&D efficiency. CRO accelerate the laboratory and hospital clinical trial processes. On a contract basis, they provide all or part of the activities involved in the drug development process to assist pharmaceutical companies in scientific or medical research. Their main services include drug discovery, safety evaluation, pharmacokinetics, pharmacology and toxicology, as well as other preclinical studies, clinical data management, and new drug registration applications. CMO accelerate factory production with a focus on drug production, providing manufacturing and packaging services for intermediates, active pharmaceutical ingredients (APIs), and preparations in the form of contract customization. Contract development and manufacturing organizations (CDMO) also provide R&D and innovation services for production processes.

Chinese CXOs have become a critical component of the global pharmaceutical R&D outsourcing system. Around the year 2000, China moved to enter the global R&D outsourcing system, offering chemical synthesis services, ahead of the joining the World Trade Organization (WTO) in 2001. Also, around the year 2000, the first batch of Chinese CXO companies emerged, e.g., WuXi AppTec and Pharmaron Beijing. These firms offered front-end entrusted processing services with low barriers to entry, such as chemical synthesis, and expanded into the pharmaceutical outsourcing supply chain. Following China's accession to the WTO, Chinese companies have gradually built trust with large overseas pharmaceutical companies and secured overseas orders by leveraging their labor and production capacity cost advantages. In 2015, the State Council issued Opinions on Reforming the Review and Approval System for Drugs and Medical Devices, outlining the direction of domestic pharmaceutical companies' innovation and transformation, and domestic demand for new drug R&D began to rise. Since joining the International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH) in 2017, China's approval system has adopted international standards, allowing domestic CXO companies to receive more back-end, high-value-added orders, including international multi-center clinical trials and preparation production. Leading CRO and CDMO companies have accumulated extensive experience after more than 20 years of development, and overseas revenue accounts for more than 70% of their total revenue on average (excluding clinical CRO Tigermed). They are part of a global system.

Chinese CROs have become globally competitive, supported by the engineer dividend.[1] Since 2000, the number of science and technology graduates in China has increased notably, and there is a large pool of high-quality professionals. China has comparatively low labor costs and a distinct engineer dividend in preclinical trials and production, resulting in cost and efficiency advantages. With global demand growing steadily, Chinese CXOs continue to benefit from demand shifting from overseas markets to China. Due to biological information security, the clinical business cannot achieve global value chain transfer and division of labor due to localized value chain management, making it difficult to expand overseas in the short term.

China's CMO contract manufacturing volume and high-value-added businesses are increasing as the manufacturing industry matures. Innovative drug production involves basic chemicals, starting materials, non-GMP intermediates, GMP intermediates, APIs, and preparations. The later it is in the production process, the higher the added value. Previously, China and major developed countries adopted different drug policies and regulations. China followed WHO standards, while major developed countries adhered to ICH standards. Innovative drugs launched overseas had to be re-registered when entering the China market, resulting in a time lag of several years. This, to some extent, resulted in a return of high-end innovative drug (including preparations) market demand to developed countries.

Meanwhile, the regulatory framework in China's pharmaceutical market was not as comprehensive in the past, resulting in limited production capacity to meet the requirements of highly regulated markets. Therefore, domestic CDMO have mostly provided intermediates used in API production, which have low added value. The

[1] China's complete industrial system and higher education system for engineering have produced many engineers which has become one of the strongest comparative advantages for China's development.

market for a single product is also small. European and US companies focus on high-value-added downstream businesses such as API and preparation production and development and application of new drug dose technologies. With increasing collaboration between domestic CXOs and overseas pharmaceutical companies, and China's adaptation to the international system after joining the ICH in 2017, the production and sales in the same region have accelerated the shift of high-end market demand to China. Chinese companies have begun to gain exposure to the API and preparation markets with high added value in the later stages of large-scale production.

CMOs and CDMOs are expanding their global presence to deal with decentralized risk. Leading CDMOs, including WuXi AppTec and WuXi Biologics, have begun a global capacity expansion cycle. In July 2022, WuXi AppTec announced plans to build an R&D and production base in Singapore, with a total investment of SGD2bn (US$1.43bn) over the following 10 years. WuXi Biologics announced a plan in 2022 to invest US$1.4bn over 10 years to build an integrated service center in Singapore that will expand its capacity and biological drug discovery, and development and large-scale production of bulk and preparations. The firm estimates it will add about 120,000 L of biopharmaceutical production capacity by 2026. As end-product manufacturing needs to be geographically close to the consumer market, most overseas pharmaceutical companies need to produce preparations overseas. Meanwhile, pharmaceutical companies have focused on expanding production capacity across multiple regions, mainly to maintain stable supply in the face of headwinds from the COVID-19 pandemic. Leading CDMOs have seized the opportunity presented by drugmakers seeking to manufacture outside of China by expanding their overseas capacity, focusing on the high-value back-end preparation business and creating synergies with the low-cost front-end business.

15.2.2 The Supply Chain for Hardware is Partly Constrained by Overseas Markets in the Near Term; Substitution is not Insurmountable

The hardware required for manufacturing is not a permanent restraint on industry development; it will take some time required for Chinese companies to gain market share. Hardware for the pharmaceutical R&D supply chain system includes scientific research equipment and reagents, factory manufacturing equipment, and consumables. Most hardware is imported since domestic innovative pharmaceutical industries are emerging and due to the requirements on outsourced orders. The reliance on imported equipment has also hampered the growth of domestic hardware suppliers. However, the COVID-19 pandemic disrupted domestic and overseas supply chains, accelerating the development of domestic hardware. Also, there was a rapid period of development in the domestic CDMO industry after 2018, with urgent demand for factory construction. In the upstream pharmaceutical equipment industry, due to unstable overseas supply during the COVID-19 outbreak, there was accelerated adoption of made-in-China equipment, with product offerings from leading domestic pharmaceutical equipment companies such as Tofflon and Truking. In the near term, products for domestic high-precision machinery manufacturing such as scientific research equipment and manufacturing equipment will lag their overseas peers. Replacing foreign products with those made in China may increase R&D difficulties and production costs. Over the long term, hardware is not a hard barrier to entry, and in time, development of Chinese products may be supported by demand, in our view.

Scientific research equipment sub-products are under development; supply of mass spectrometers and other products may be limited in the short term. R&D of life science research equipment in China is in its infancy. Localization rates have increased notably in fields with low technological barriers, such as direct digital radiography and blood diagnosis. However, the localization rate remains low for high-end research equipment such as mass spectrometers, chromatographs, endoscopes, and gene sequencing devices. Foreign brands dominate the manufacturing of some devices, and many analytical instruments used by pharmaceutical companies are in limited supply.

Localization may be achieved for scientific research reagents. The biological reagent industry has largely matured in developed markets such as the US and Europe, and the competitive landscape is relatively stable. Leading companies have gained economies of scale through M&A, among others, and market share. The industry is thus more concentrated, and firms with global influence have emerged, such as Thermo Fisher. In China, the biological reagent industry started relatively late. Chinese biological reagent companies have competitive disadvantages in business scale, financing channels, and their relatively short period of development. They also tend to lag overseas companies in key raw material technologies, production processes, product variety, and product quality. The COVID-19 pandemic disrupted global supply chains, accelerating the replacement of imported goods with Chinese-made reagents. For example, in 2020, the overseas supply of upstream raw materials required for nucleic acid PCR test kits was in short supply, and domestic demand for nucleic acid tests accelerated the use of domestic raw materials. This accelerated the development of companies in the life research reagent industry such as Vazyme, ACROBiosystems, and Sino Biological. As demand for biological reagents is relatively customized and fragmented, the likelihood of any interruption to the production of core products from fluctuating overseas supply is relatively low.

Imported pharmaceutical equipment dominates the Chinese mainland market; domestic products gaining market share. Chinese companies lag foreign leaders in equipment technology and performance. However, as the pharmaceutical equipment industry is still emerging, as technology develops and accumulates, pharmaceutical equipment companies with strong R&D and competitiveness, such as Tofflon and Truking, have gradually emerged. As domestic demand grows, we expect Chinese brands to gain market share and outperform imported brands.

15.3 Software Construction in the Pharmaceutical Ecosystem Has a Long Way to Go

The core of drug supply lies in the development and marketing of new drug molecules. The value of pharmaceuticals lies in the development of new drugs to address clinical needs rather than the construction of manufacturing capacity. In other words, compared with R&D services and suppliers, the product end, with higher GM and revenue, is at the top of the value chain. Blockbuster drugs with both clinical value and innovation perform strongly in commercialization. A single blockbuster drug can drive rapid growth of pharmaceutical companies. Sales of the world's top 10 drugs combined exceed US$100bn, with sales of three of these drugs each exceeding US$10bn in 2020. Most of these blockbuster molecules are products from European and US pharmaceutical companies.

The US is the world's major developer of drugs and market for new molecules and commercialized products. We believe the competitive landscape of the US drug market has remained stable, largely due to the patent system and strict regulatory requirements, which ensures the commercialization potential of drugs, drives ongoing R&D investment from the capital market and the pharmaceutical industry, and directs the development and iteration of the R&D system for new drugs. In 2020, US pharmaceutical companies contributed 51% of new drug molecules, and nine of the world's top 10 best-selling drugs were introduced to the market by US pharmaceutical companies. US firms accounted for 46% of global biotech companies in 2019. In 2020, nine of the world's top 20 pharmaceutical companies were headquartered in the US. Strong end-market demand and payment system are solid drivers of R&D at pharmaceutical companies.

Globally, a large proportion of high-value new drugs come from European and US multinational pharmaceutical companies. Due to the high R&D cost of new drugs, a division of labor has formed in mature markets in Europe and the US. After completing proof of concept, small- and mid-size enterprises often cooperate with large multinational pharmaceutical companies with cash on hand, mature clinical and commercialization platforms, and a need to expand their pipelines through co-development, licensing, or sales. This division of labor has resulted in European and US multinational pharmaceutical companies gaining a majority share of new drug molecule development (Fig. 15.3).

Chinese pharmaceutical companies are transforming and catching up with foreign companies; Chinese firms and products are not yet globally competitive. China's pharmaceutical industry is comparatively young, and the domestic drug market is fragmented. The most profitable comprehensive pharmaceutical companies tend to focus on generic drugs, while their new drug businesses are undergoing transformation and following innovations from overseas, and most of their products are not yet globally competitive. Pharmaceutical and biotech companies that have grown rapidly in recent years and focus on innovative drugs are growing (Fig. 15.4).

Pharmaceutical innovation in China is catching up to global peers; innovation capability developing. R&D of new drugs in China has accelerated since 2015. In

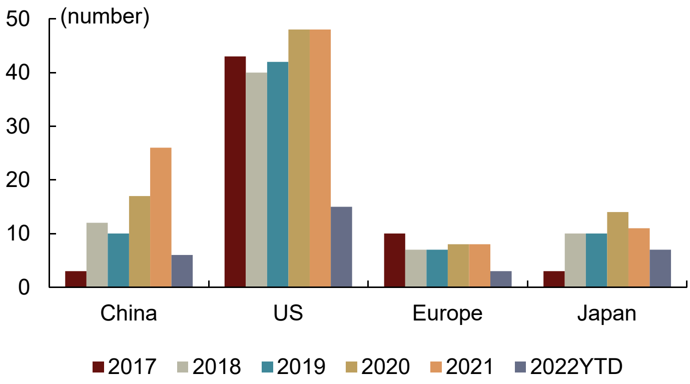

Fig. 15.3 The number of new approved drugs by region. *Note* Data as of August 2022. *Source* Pharmacodia, CICC Research

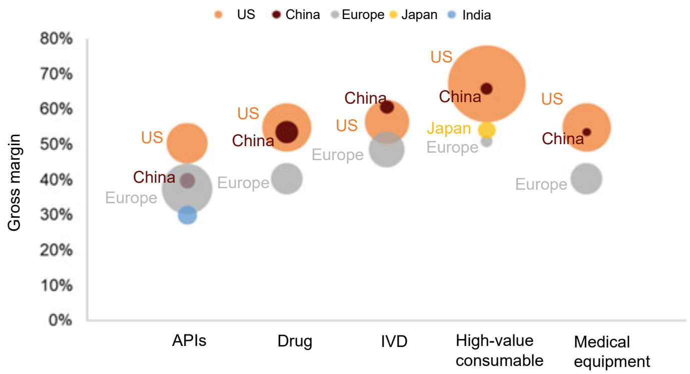

Fig. 15.4 Comparison of revenue and GM of key global pharmaceutical companies. *Note* The size of the bubble is the relative size of revenue of the top 10 companies in each region in 2021. IVD = in vitro diagnostics. *Source* Company announcements, CICC Research

recent years, early entrants to the market have begun to generate income. However, the increasing number of clinical trials for the same drug targets is creating homogeneous competition. Most domestic innovative drug companies adopt a "me-too" or "fast-follow" strategy,[2] which has a higher success rate. Based on their understanding of their European and US peers, Chinese companies have leveraged the advantages in being a late-mover to catch up with international best practice. For some targets, the progress of Chinese companies has already reached the same level as global leaders. However, excessive competition is inevitable as most limited development and clinical resources are allocated to popular, highly homogeneous targets. In 2019, the number of targets undergoing clinical trials was 550 in the US vs. 160 in China,

[2] A me-too strategy refers to innovation based on the original drug. The fast-follow strategy avoids patent protection to rapidly develop new drugs with the same effect.

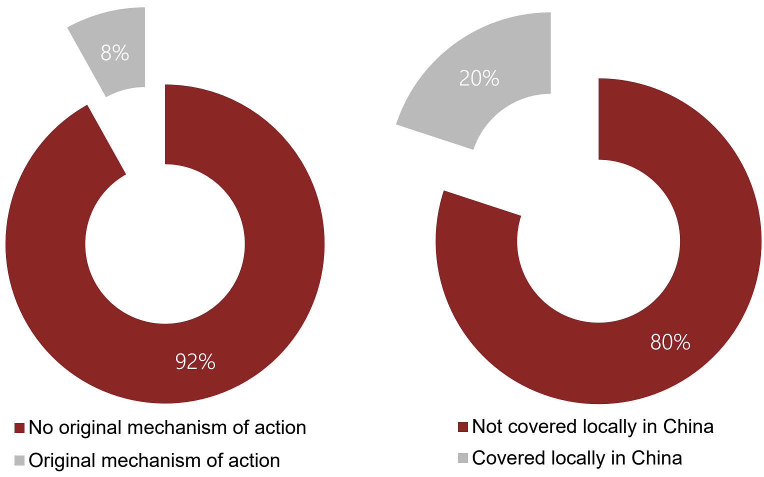

Fig. 15.5 Homogeneity has increased in China's drug R&D (2017–2020). *Source* Deloitte, CICC Research

implying smaller coverage of targets. Furthermore, clinical trials for targets are more homogeneous in China. In the US, 70% of clinical resources are allocated to the top 30% of targets. In China, 70% of clinical assets are used to support the top 21% of targets, according to Pharmaproject, which suggests a waste of clinical resources (Fig. 15.5, Fig. 15.6).

China has established a pharmaceutical R&D ecosystem, and its regulatory system is improving to a stage of adopting more international standards. However, basic scientific research, the capital market, and the payment system have room for improvement. Since the 2015 drug approval and medical insurance reforms,[3] institutional standards and the investment focus of the drug companies have become clearer, with progress being made overall. However, there are gaps in the STEM-based disciplines, especially in chemistry, biology, and pharmacology. We believe the construction of discipline and talent systems could be improved. Furthermore, current incentives for innovation investment are insufficient, financing arrangements are inefficient, and payment capability from the market has not been fully exploited.

15.3.1 Regulatory System: Breakthroughs in Reforms of Drug Review; Modern Approval System Improving

The 2015 drug review and approval reforms clarified the therapeutic value of innovative drugs in clinical trials. Since the review, a series of mechanism innovation reforms

[3] A suite of policy changes introduced in 2015 included changes that accelerated drug approvals and encouraged innovation.

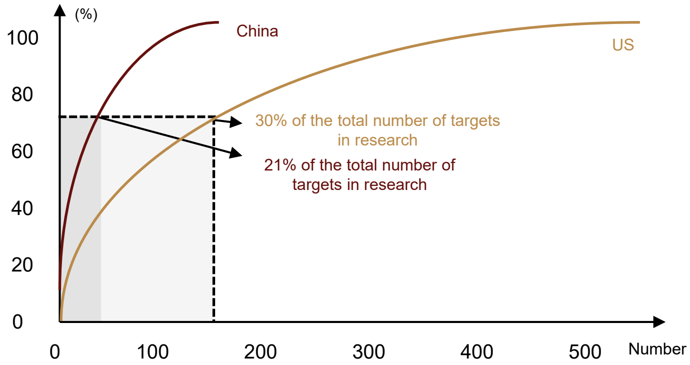

Fig. 15.6 The number of targets corresponding to clinical resource utilization (2019). *Source* Pharmaproject, CICC Research

have since begun. The Chinese pharmaceutical industry's innovation ecosystem has gradually improved, and the industrial structure has been optimized, providing the necessary conditions for growth of the domestic innovative drug industry.

- Optimizing processes to accelerate the review and approval of new drugs while reducing system and regulatory costs. To ensure safety, regulators can grant more rights to enterprises, institutions, and markets, allowing them to take on more responsibility. The National Medical Products Administration (NMPA) system for clinical trial applications has shifted from being approvals based to expiration based. The NMPA has a system for authenticating the qualifications of institutions to reduce the approval time for clinical trials and to improve the ability of and incentive for medical institutions to take part in trials. The 2020 Provisions for Drug Registration provides four channels that accelerate the launch of new drugs: Conditional approval, breakthrough therapy designation, priority review, and special review. On the supply side, review capabilities might also be improved. The Center for Drug Evaluation (CDE) increases the number of reviewers and improves efficiency of review.
- China's regulatory system continues to adopt international standards. The NMPA joined the ICH in 2017 and was elected to its management committee in 2018. The highest international technical standards and guidelines are being introduced, pushing the scientific development of drug registration standards, and accelerating coordination and unification of technical requirements for drug registration with international requirements. China is integrating further into the international innovation system in all aspects of new drug R&D, incorporating its drug regulatory system into the international framework and gradually entering the global pharmaceutical market
- Clarifying the significance of intellectual property protection in encouraging pharmaceutical innovation. After the passing of the Patent Law of the People's Republic of China (2020 Amendment), China implemented a drug patent term

compensation system that adopted international standards, providing appropriate patent term compensation for time to market for innovative drugs occupied by review and approval and establishing drug patent linkage. Drug regulators and patent departments jointly develop measures to resolve patent disputes in drug marketing approval and licensing applications, establishing an early resolution mechanism for drug patent disputes. This process can also improve the protection of drug test data.

- Improving reviews and approvals guide the industry to BIC and FIC innovative drug development; raising barriers to entry has led to low-quality capacity exiting the industry; guiding the industry to reduce competition and duplicated and inefficient use of R&D resources; guiding companies to achieve healthy accumulation in the newer direction with higher clinical value. The CDE released Guiding Principles for Clinical Value-Oriented Clinical R&D of Antitumor Drugs in November 2021. The document emphasizes the quality requirements for clinical research design of new drugs from the policy end, echoing international guidelines from organizations such as the FDA and ICH and imposing high requirements for innovation quality.

15.3.2 Scientific Research System: Basic Science Emerging; Efficiency of Results Transformation Needs to Be Enhanced

Reforms to the drug review process have unlocked the impetus for innovation in the pharmaceutical industry, in our view. The skilled worker system for clinical trials and manufacturing in China's innovation system has also improved greatly in the past few years, but there is still much room for improvement in the development of basic and translational science and skilled worker systems. Over 2015–2019, the average citation frequency of US theses in biology and medicine was 2.5× and 4× that of China, and the journal impact factor of papers in the life sciences in the US was 12,185 in 2019, much higher than China's 2,722. There are currently few academic leaders capable of breakthroughs in innovations, in our view. We believe the absolute amount of published high-level academic articles is increasing, but the industry lacks achievements that are successfully translated into new drugs in pipelines or in markets.

There is room to improve the efficiency and mechanisms to commercialize scientific and technological achievement. The concept of "from labs to hospital beds" was proposed in 1992, and encapsulates the rapid and effective translation of basic research in medical biology into theories, technologies, methods, and drugs that can be applied in clinical practice. The US National Institutes of Health (NIH) formally proposed and formulated a roadmap for translational medicine in 2003. It established a clinical and translational science fund in 2006 and the National Center for Advancing Translational Science in 2012. It has built a national network of academic medical centers, and there many professionals that bridge the gap between basic research and clinical practice. More recently, China has established a basic system for technology transfer, but translational medicine is still in its infancy. Most of China's scientific and technological achievements come from research institutes rather than corporates, resulting in a substantial disconnect between scientific and technological achievements, and industrial integration. We believe some alliances aimed at commercializing scientific and technological results are relatively loose, and they find it difficult to form synergies.

15.3.3 Investment System: Investment Volume Rising Rapidly; Specialized Basic Research and Structure Still Need to Be Optimized

Investment in basic research is low in China, accounting for around 5.5% of total R&D investment in 2018 (vs. 16.6% in the US, 12.6% in Japan, 18.3% in the UK, and 22.8% in France). Most R&D funds are spent on experimental development, and the amount spent on basic research has notable upside potential. Most developed countries have established a biomedical research management system to ensure the direction of basic medical research investment across different specialties and multiple projects. For example, the NIH uses 80% of the nearly US$40bn it manages to support non-hospital research institutions via 24 research institutes in sub-disciplines, helping to fund US research in cutting-edge areas of medicine. In 2019, China's public sector spent more than Rmb20bn on medical specialties such as biochemistry, physiology, microbiology, anatomy, pathology, and pharmacology medicine. Funding mainly comes from the Ministry of Science and Technology, the National Health Commission, the NMPA, the National Natural Science Foundation of China, and medical universities.

The established pharmaceutical capital market in the US improves capital utilization efficiency, and tiered funds improve innovative R&D risk identification and resilience. As the birthplace of venture capital, the US has a relatively professional pool of investors and a mature pricing and valuation system for the pharmaceutical industry. Together with a well-built technology transfer system, this allows the US to better leverage the capital market and share the risk in commercializing cutting-edge innovations. Meanwhile, secondary markets such as the Nasdaq offer an exit route for venture and equity investment, reducing the cost of exit. We think the US experience sets an important example for China. Tolerance of project failure can be increased through the stratification of innovative financing and conventional financing, and raising the barriers to entry for innovative financing. Investment institutions are stratified, and investments are made in professional projects. This can improve the identification of innovative projects and the NMPA's ability to supervise new projects. Exploring the financial derivatives business can also dilute the impact of the failure of specific innovative drug projects.

China's financing system is improving, but further specialization is required. Since 2014, the accelerated growth of investment in the medical industry has been a major driver of growth in drug innovation. The introduction of Chapter 18A listings, which is mainly relevant to biotechnology companies, and the SSE STAR Market have provided a channel for the listing of biotech companies in China, and the improved capital exit mechanism is attracting substantial investment. Data from VBDATA.cn shows that domestic investment and financing in the biopharmaceutical sector rose 26.0% YoY to Rmb111.36bn in 2021, and financing events increased by 53.1% YoY to 522. However, the quality of investment targets varies. Funds have flowed to areas with repeated construction, and valuations of some bids have been too high.

15.3.4 Payment System: Lack of Commercial Insurance Payers; High-Risk, High-Reward Incentive Mechanism Needs to Improve

The US is the world's largest drug market, with most consumer spending on pharmaceuticals flowing to innovative drugs with clinical value. According to the Institute for Clinical and Economic Review, willingness to pay among US patients is US$100,000–150,000/quality-adjusted life year.[4] Annual sales in the US drug market reached US$555bn in 2021, ranked No.1 globally and accounting for 47% of global market sales. The US patent, regulatory, and pricing systems focus on the innovative and clinical value of drugs, which increases pharmaceutical companies' pricing power for new drugs. The US payment system can pay a premium for innovation. According to the Pharmaceutical Research and Manufacturers of America (PhRMA) and IQVIA, original, patent-protected drugs accounted for 9% of prescriptions in the US in 2020[5] but 80% of sales, and the market share of original drugs whose patents have not expired accounted for 66% of prescription drugs in 2018, with the majority spent on new drugs.

China has a large drug market in absolute terms, but per capita spending is low. China's population is large and its drug market is second only to the US in terms of absolute size. Per capita spending on drugs, however, is low. According to the 2019 China Health Statistical Yearbook and OECD data, China's per capita healthcare expenditure in 2019 was around US$700, accounting for 6.67% of GDP, and per capita drug spending was about US$260. In the same period, per capita healthcare spending in the US was around US$12,000, about 17.6% of GDP, and the per capita prescription drug spending (excluding over the counter [OTC]) was US$1,128 (Fig. 15.7, Fig. 15.8).

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[4] Refers to an adjusted life expectancy which is used to evaluate and compare health interventions.

[5] Original new drugs.

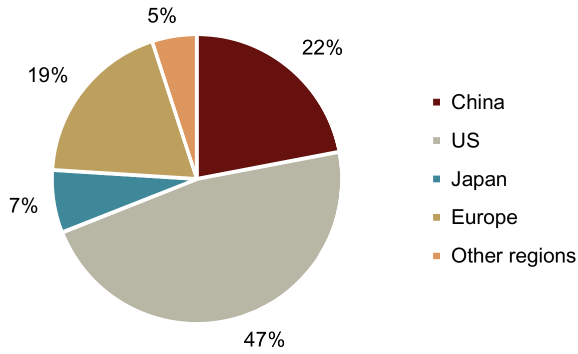

Fig. 15.7 Breakdown of the global drug sales market (2021). *Source* Statista, Atradius, IQVIA, CICC Research

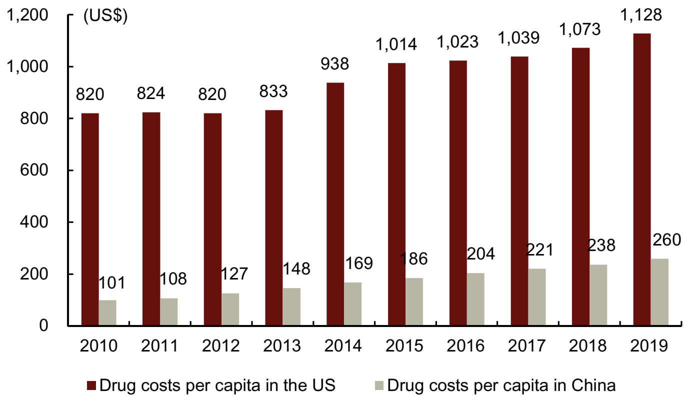

Fig. 15.8 Comparison of per capita drug spending in China and the US (2019). *Source* CMS, Ministry of Commerce, National Bureau of Statistics, CICC Research

The potential revenue from the Chinese market has yet to be fully realized, and market structure is not yet mature. Since the drug review and medical insurance system reforms of 2015, China's pharmaceutical market has undergone substantial structural changes. However, generic drugs, TCM injections, and adjuvant drugs account for a large share of China's drug market, reducing room for payment for innovation outcomes. The efficiency of fund utilization needs to improve as well, in our view.

NHSA reform efforts are yielding results, creating scope for innovations in payment. Since 2016, government departments and commissions, as well as the NHSA, have launched reforms to the list of drugs to be monitored, normalization of centralized procurement of generic drugs, optimizing of the adjustment mechanism for the medical insurance drug list, increasing the frequency of updating the medical insurance drug list, and reducing the time for participating in negotiations on the access of new drugs. Through these processes, the number of drugs included in the medical insurance program has risen each year, and the increase in medical insurance negotiations has greatly reduced the institutional cost of introducing innovative drugs for treatment covered by medical insurance and accelerated the realization of the commercial value of new drugs. Meanwhile, the market for drugs and generics with unclear clinical value has shrunk, with a greater proportion of funds from medical insurance paying for innovative drugs, forcing pharmaceutical companies to shift their product strategies towards innovative drugs.

The payment system requires guidance; should seek to maximize multi-level payments. China's national medical insurance program, China Healthcare Security, is the largest payer in the pharmaceutical market, and, in our view, should work to prioritize coverage of broader medical needs and drug accessibility. The program has a simple financing system and payment policy, with the strength to bargain on prices. These factors, as well as China's competitive landscape and ongoing economic development, drive China's innovative drug market to lower prices. New drugs such as PD-1 monoclonal antibodies are much cheaper in China. Meanwhile, drugs paid for out-of-pocket account for a large proportion of all pharmaceutical sales in China, and the payment system has not fully met the needs of patients and their willingness to pay. Commercial insurance dominates the US payment system, and its government-led basic medical insurance primarily covers vulnerable groups. Specifically, commercial insurance companies mainly target the working-age population and offer customized products to meet the needs of various groups. They explore different groups of people's differing medical needs and willingness to pay and maximize multi-pillar payment capabilities.

However, for insurance names in China, obtaining the usage data of medical terminals is crucial to their product design, total expenditure control, and risk control. At present, commercial health insurance mainly targets individual policyholders, and their data is mainly unstructured data provided by policyholders. The lack of data in the healthcare system, especially among public hospitals, hinders commercial insurance companies from planning and designing insurance products. Lack of data transparency also makes risk control more difficult for underwriting and claim settlement, and there is a serious problem of information asymmetry between agents and users in the insurance market. We expect the establishment of the hospital drug data system to accelerate the introduction of commercial insurance and exploration of commercial insurance payment, introducing incremental capital to the payment system in China's pharmaceutical industry and easing the long-term burden on the national medical insurance program.

15.4 Thoughts and Implications: Policy Guides Improvement of Software Ecosystem; Marketization to Incubate Strong Pharmaceutical Companies

15.4.1 A New National System That Creates a Favorable Environment for Pharmaceutical Innovation and Development

Increase investment in basic and translational science, driving the industrialization of research results. The scientific research system can use public sector funds and policies to continue to attract high-level skilled workers. It can improve infrastructure construction for technology transfer and commercialization of scientific research output, and give play to the guiding role of government funds to support commercialization and exploration in high-risk areas.

The regulatory system can further optimize the approval system and encourage cutting-edge innovations. We think regulators can remove policy barriers in cutting-edge fields and improve patent and data protection systems. Regulators can create a socialized incentive mechanism to guide innovation, increase the efficiency of preclinical and clinical resource allocation, and encourage innovation. They can also expand the regulatory system, launching systematic training programs and capacity development system construction that meet global innovation standards, improving regulatory institutions' professional capabilities, and creating an approval and review system for independent R&D of innovative drugs.

Investment system: Fund stratification improves risk identification and resilience of innovative R&D while stimulating the vitality of social capital. The stratification of innovative and conventional financing can raise the barriers to entry for innovative financing, increase tolerance for project failure, and help establish a healthy investment system. Investment institutions should be set into different categories to support professionals investing in projects in areas of their expertise, so as to improve the authenticity of innovative projects. Financial derivatives investments might be explored. ETFs, for example, can help investors dilute the impact of a specific innovative drug project's failure, and customized products can meet the needs of investors with varying risk appetites.

Payment system: Building a diversified payment system to introduce incremental volume to pay a reasonable premium for innovation. The market can build an integrated hospital medication data system, accelerate the entry of commercial insurance, and explore the potential of commercial insurance payment to introduce incremental volume to the pharmaceutical industry's payment system and ease the burden of forward payment in the national medical insurance program. The market might further reduce the entry cost of new drugs into the insurance system, improve the drug evaluation system and drug management system, and use medical insurance funds rationally and efficiently based on clinical value and patient benefits. The market should support the pricing system for original and innovative products. The high-risk, high-reward mechanism may accelerate the stratification of financing and boost high-risk original drug innovation.

15.4.2 Localization of Upstream Hardware is an Imperative; Localizing Key Supply Chains Can Solidify Ecosystem

The rise of Chinese companies is imperative upstream; localizing key supply chains could solidify the ecosystem. The number of domestic companies in the life science research equipment value chain is relatively low. To make technological breakthroughs, China faces high barriers to entry in R&D and innovation in products. Furthermore, from core components to machine integration, equipment products involve a wide range of disciplines, requiring skilled workers with diverse backgrounds. Aside from breakthroughs in product R&D and product performance comparison, downstream commercial customers highly recognize foreign brands' derivative services such as maintenance and replacement. There is scope for breakthroughs in commercializing upstream domestic life research equipment, in our view.

With China's continuous support for skilled worker training and policy catalysts, we expect Chinese companies to gradually accumulate the underlying technical knowledge involved in product R&D, facilitating breakthroughs in innovative technologies. Meanwhile, as the business ecosystem changes and domestic brands focus more on customer needs, the overall proportion of Chinese companies upstream and downstream will likely increase further, stabilizing the domestic life science research supply chain ecosystem.

Chapter 16
The Globalization of Chinese Home Appliance Brands: A Long Way to Go

Abstract China is one of the world's largest manufacturers of home appliances. The country's home appliances market is dominated by domestic brands, which have started to gain an advantage over foreign competitors. The industry chain exhibits a smiling curve, with brand globalization and upstream core electronic components being the high value-added segments into which China's home appliance industry has yet to venture. In this report, we analyze the development and characteristics of the home appliance industry, and study opportunities and challenges presented by the globalization of the industry, with a view to shedding some light on the path to its future growth.

China is one of the world's largest manufacturers of home appliances but has weak brand visibility globally. (1) The world has witnessed the shift of the home appliance value chain from Europe and the US to Japan and South Korea, and more recently, to China. However, the overseas home appliance market is still dominated by global brands from Europe, the US, Japan, and South Korea, with Chinese brands having a weak presence. (2) Low labor costs, strong domestic demand, and well-equipped supporting facilities of the industry chain were major contributing factors to the rise of China's home appliance industry, which is now facing mounting pressure from rising labor costs and relocation of production capacity to other countries. This has prompted China to move to higher value-added activities by globalizing its brands. (3) China has a comprehensive home appliance industry chain, but relies heavily on foreign companies for the supply of some components (e.g., chips and raw materials of liquid crystal display [LCD] panels), and could face critical technological hurdles in extreme cases. A lack of brand awareness may also bring volatility in demand.

Globalization presents both opportunities and challenges. (1) The US is one of the most important home appliance markets. The US tariffs have led to the relocation of some home appliance production capacity to regions such as Southeast Asia, where home appliance industrial clusters could potentially emerge to compete with China. (2) The Indian home appliance market has great potential, and the country is

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attracting foreign investment through tariffs. However, Chinese companies confront certain restrictions, posing challenges to their presence in the fast-growing Indian market. (3) Chinese home appliance companies are striving to globalize their brands through a variety of formats. Following rapid growth in 2020 and 2021, China's home appliance exports are facing downward pressure as headwinds, including high inflation and energy crises, erode purchasing power and reduce at-home consumption in Europe and the US.

Thoughts and implications: (1) We believe Chinese home appliance companies might follow the industry trend of going global: By leveraging domestic success in the development of industrial clusters, China could collaborate with Southeast Asian countries on cultivating new home appliance industrial clusters in a way that benefits Chinese companies, and encourage large home appliance groups to lead and share their knowledge and expertise with inexperienced companies regarding how to build a presence in overseas markets. (2) China could adopt a tiered deployment of production capacity while continuing its opening-up policy in a bid to achieve a higher degree of import substitution. Home appliance manufacturing spans a variety of industries, with core technologies mainly originating from upstream segments. The restraints on China's high-end technologies may undermine the innovation of China's home appliance industry. (3) China can also turn technological advantages into standard advantages through active participation in the formulation of international standards.

Keywords Brand globalization · Evolution of China's home appliance industry · Home appliance capacity relocation

In this report, we analyze the evolution of China's home appliance industry to assess its current competitiveness and identify the direction of its future development. We also examine the characteristics of the industry to recognize the patterns of its development.

China's home appliance industry started to develop in the 1980s, followed by the entry of a large number of foreign companies into China in the 1990s that brought with them advanced production technologies and management experience. Since China's accession to the World Trade Organization (WTO) in 2001, the country has benefitted from free trade and witnessed rapid growth in both domestic and overseas sales of home appliances. Retail sales of home appliances and audio equipment in China increased from Rmb95.3bn in 2002 to Rmb934bn in 2021, fueling the emergence of national brands such as Haier, Midea, and Gree, which were later joined by innovative brands such as Roborock and XGIMI. China's home appliance exports jumped from US$8.8bn to US$98.7bn over 2002–2021.

Chinese large appliance companies began to go global in 2010, but were in a weaker competitive position *vis-à-vis* their international rivals. By 2020, they had become more competitive globally, with home appliance production capacity increasingly concentrated in China. At the same time, Chinese companies made active efforts to expand their international presence via various strategies, catalyzing a trend of brand globalization. However, it is worth noting that Chinese brands are still struggling with international visibility, and facing the threat of industrial relocation caused by the deglobalization policies. China still has a long way to go before transforming itself from a home appliance manufacturing power into a global brand builder.

Low labor costs, strong domestic demand, and well-equipped supporting facilities of the industry chain were major contributing factors to the rise of China's home appliance industry.

- The home appliance industry is moderately labor-intensive and moderately asset-intensive. Labor cost advantage was conducive, though not decisive, to its early-stage development. For example, home appliance companies moved some of their production capacity from Japan to Southeast Asia in the 1980s, which, instead of boosting local home appliance industries, has sustained the situation in which foreign companies produce locally even today in the absence of influential homegrown brands.
- Strong domestic demand can attract foreign investment, bringing advanced production technology and management experience to the host country during the early stages of development of local companies and paving the way for the growth of homegrown brands as the market expands. This is how Chinese firms have built up their economies of scale. In China's home appliance industry, it is homegrown brands (e.g., Haier Smart Home) and innovative companies (e.g., Roborock) rather than original equipment manufacturing (OEM) service providers that have become globally competitive and continue to expand overseas. OEM companies rely heavily on orders from brand owners and tend to suffer from unstable supply chain caused by the bullwhip effect of weakening demand. For example, home appliance demand in Europe and the US has been falling since 2022. As a result, most of the companies that focus on providing OEM services to European and US home appliance brands saw significant declines in their revenue.
- Home appliance manufacturing spans a variety of industries, with core technologies mainly originating from upstream segments. China has a comprehensive home appliance industry chain with well-equipped supporting facilities, and some home appliance leaders have also built integrated value chains. For example, leading air conditioner (AC) manufacturers Gree and Midea have achieved domestic production of AC compressors, motors, variable frequency controllers, and microcontroller units (MCU). Japan and South Korea are also among the major industrialized countries in the world, and enjoy advantages in variety of industries. These two countries were once home to a major share of global home appliance production capacity. China has moved some of its home appliance capacity to Southeast Asia, but remains the exporter of core components.

The main force that drives the development of the home appliance industry is market competition, supported by industrial policies. Key industrial policies include:

- Consumption stimulus policies such as subsidized sales of home appliances in rural areas and home appliance trade-in programs;

- Policies aimed at adjusting the structure of consumption, including the granting of subsidies for energy-efficient home appliances and mandatory increases in efficiency standards for home appliances. The transition to a green and low-carbon economy has attracted increasing global attention and catalyzed the introduction of various supporting policies. Countries compete with each other in greening and decarbonizing their industry chains, where China enjoys a competitive advantage. For example, the AC refrigerants can be categorized into four generations.[1] Hydrofluoroolefins (HFOs) are the fourth-generation refrigerant, and have yet to be industrialized due to high production costs of fine chemicals. To date, the HFO-based refrigerant jointly developed by Honeywell and DuPont has been promoted in Europe and the US, and Chinese companies Zhejiang Juhua and Shanghai 3F New Materials are already capable of producing it. Gas boilers used to be the main source of heating that kept Europe warm in the winter. However, European countries began to encourage the use of air-source heat pumps due to natural gas shortage and a broader push to reduce carbon emissions. The REPowerEU plan, presented by the European Commission in May 2022, targets the addition of 10mn heat pumps in the next five years, resulting in a surge in China's heat pump exports.
- Industrial policies in upstream industries, including panels and LED chips, can help overcome critical technological hurdles of core components. China's policies for asset-heavy semiconductor sectors such as panels and LED chips are similar to those adopted by South Korea for the panel sector in the past – government-subsidized reverse investment – which have paid off. However, it should be noted that such policies are not suitable for the home appliance industry due to differences between the industries. So far, China has not achieved domestic production in the semiconductor industry, and still relies heavily on foreign companies for the supply of raw materials used to produce chips and LCD panels.

16.1 Industrial Characteristics of Home Appliances

16.1.1 Home Appliances Involve Multiple Industries, With Core Technology Originating From the Upstream Segments

Home appliances represent a comprehensive application of technologies from various upstream industries. The home appliance industry involves a wide range of upstream manufacturing industries (Fig. 16.1), such as electronics, machinery, new energy, and manufacturing equipment, as well as raw materials such as steel and non-ferrous metals. As smart products become increasingly popular in the Internet of Things (IoT) era, the computer and artificial intelligence (AI) industries have become an

[1] GAO Enyuan, and HAN Meishun. "Analysis on Refrigerant Products Market of China in 2020." *Chinese Journal of Refrigeration Technology* 41.S01(2021):9.

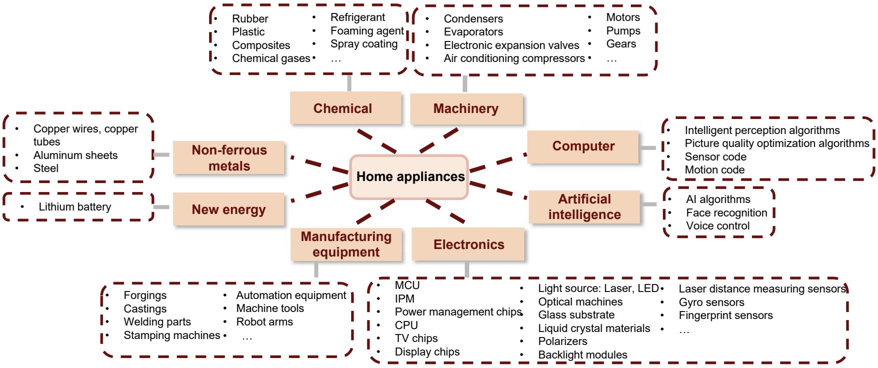

Fig. 16.1 Home appliances are a comprehensive application of technologies from various upstream industries. *Source* CICC Research

essential part of the upstream industry chain of home appliances. Core technologies from upstream industries have a considerable impact on the development of home appliances, and the sustainable development of the industry relies on the development of upstream technologies and processes such as chips, AI algorithms, and new materials.

16.1.2 A Large Variety of Product Categories; Different Components

Home appliances have a wide variety of product categories and different components. Looking at AC, vacuum cleaners, TVs, and projectors as examples, their components vary from each other, but their upstream industries are similar. First, most home appliances are made of basic raw materials such as metal and plastic. Second, different types of chips are used to manufacture various home appliances. The R&D and manufacturing of select chips remain the challenges to be overcome in the industry chain. Specifically, the proportion of China-made intelligent power modules (IPM) applied in air conditioners, the CPU of vacuum cleaners, and the display chips in projectors remains relatively low. In addition, China still relies on foreign companies for the supply of display chips in projectors. Apart from the raw materials and chips mentioned above, the manufacturing of vacuum cleaners also involves AI algorithms, voice control, and lithium batteries.

16.1.3 The Home Appliance Value Chain Resembles a Smiling Curve

The distribution of value added along the home appliance industry chain resembles a smiling curve, with a relatively high gross margin at the two ends of the curve. The two ends are where China's home appliance industry may be heading in the future. In 2021, the gross margin of branded manufacturers of large home appliances, kitchen appliances, small home appliances, and TVs was 28.9%, 46.6%, 38.1%, and 18.3%. In contrast, the gross margin of OEM businesses for these home appliances was only 8.7%, 11.6%, 15.9%, and 12.0%, much lower than that of branded businesses. In addition, in terms of upstream accessories and electronic components, the gross margin of mechanical components such as air conditioner compressors and refrigeration valves was 13.2% in 2021. In contrast, the gross margin of manufacturers of electronic components MCU, insulated gate bipolar transistors (IGBT), and IPM was 47.1%, 37.1%, and 28.2%.

16.1.4 Demand and Supply Equally Important; Visible Global Demand Risk

Both demand and supply of the global home appliance industry have a large impact on China's home appliance industry. Therefore, demand and supply are considered crucial factors in the analytical framework of this report. Home appliances are a mid-tech industry, and efficiency varies among different countries. However, the supply of home appliances might be easily substituted if efficiency is excluded from consideration. Efficiency is a critical competitive advantage in the era of free trade. However, against the backdrop of deglobalization in some markets, efficiency may become less influential in determining the development of the home appliance industry.

16.2 A Home Appliance Manufacturing Power With a Well-Established Industry Chain

Since China's entry into the WTO in 2001, China's retail market for and exports of home appliances have been growing rapidly. China has become one of the world's largest retail markets for home appliances. According to China's Ministry of Industry and Information Technology, the revenue of home appliance firms above a designated scale (including their non-home appliance businesses) was Rmb1.7trn in 2021, with earnings of Rmb121.9bn. AVC data shows China's retail sales of home appliances reached Rmb760.3bn in 2021. Data from China's General Administration of Customs shows China's export value of home appliances (including TVs, DVDs, and some white appliances) reached US$98.7bn in 2021. As a manufacturing power in the

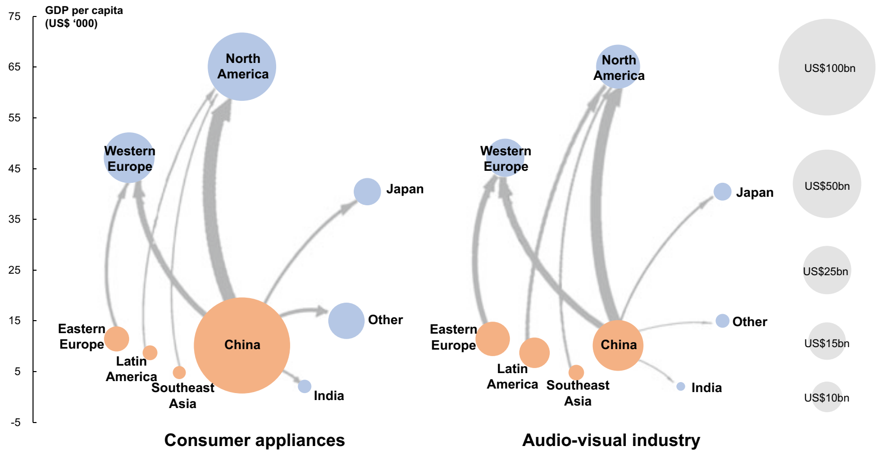

Fig. 16.2 Illustration of international trade of consumer appliances and audio-visual industry (2021); China is the world's largest net exporter of home appliances. *Note* 1. We use the international trade data from UN Comtrade in 2021. The bubble size represents the net import and export value of each country or region; orange or blue marks each country or region as a net exporter or net importer, respectively; and the thickness of the line represents the net export value of the net exporter. 2. Consumer appliances include air conditioners, refrigerators, washing machines, vacuum cleaners, electric shavers, stand mixers, fans, massage apparatus, and electric heating appliances. The audio-visual industry refers to televisions, stereos, and set-top boxes. *Source* UN Comtrade, World Bank, CICC Research

global home appliance industry, China has become the world's largest net exporter of home appliances (Fig. 16.2).

China now faces few technological hurdles in its consumer appliance industry. The country remains reliant on foreign enterprises for the supply of some high-end electronic components. Chinese mainland companies have ramped up their production capacity in MCU, IGBT, IPM, and other electronic components. (1) MCU: China is now self-sufficient in core MCU components for home appliances, and some Chinese companies are able to produce components for 22nm and above processes. (2) Certain Chinese companies have reached a relatively leading position in signal chain analog chips[2] and power management integrated circuits[3] related to home appliances. (3) IGBT and IPM: We expect the market share of Chinese mainland companies to rise rapidly amid the expansion of production capacity.

China is a global leader in the manufacturing and sales of panels and audio-visual equipment. However, the proportion of China-made cutting-edge core components used in audio-visual equipment remains relatively low. Looking at TVs as an example,

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[2] The signal chain analog chip is an integrated circuit that is able to send and receive, convert, amplify and filter analog signals.

[3] The power management integrated circuit is a chip that is responsible for the conversion, distribution, detection, and other power management of electrical energy in electronic equipment systems.

the basic materials for TVs mainly include panels, backlights, driver ICs,[4] and CPUs from a wide variety of sub-industries, as well as glass substrates, liquid crystal materials, and polarizers in the upstream industries. China leads the world in the production capacity of panels. However, the proportion of China-made core raw materials from the upstream TV industries remains relatively low.

Regarding core components: (1) The asset-heavy, capital-intensive LCD panel industry with high barriers to entry is dominated by Chinese mainland companies. By learning the counter-cyclical strategy from South Korea, Chinese mainland companies have been active in building their panel production capacity. The panel production capacity of the Chinese mainland exceeded that in Japan in 2016 for the first time and exceeded that in South Korea and the Taiwan region of China in 2018. (2) The supply of glass substrates is dominated by US and Japanese companies. Incumbent producers of glass substrates, a core component in manufacturing LCD panels, are protected by barriers to entry in terms of technology process, formula, and manufacturing equipment. The major global suppliers of glass substrates include Corning from the US and AGC and NEG from Japan. In addition, Chinese mainland companies also have production capacity for the component. (3) The supply of LED and TV chips is dominated by companies from the Chinese mainland and the Taiwan region of China. (4) Texas Instruments enjoys an exclusive digital light processing (DLP) patent. The light engine of projectors includes light source, light modulation, and lens. Specifically, light modulation has a large impact on major display indicators excluding brightness. Projectors are based on one of the three imaging technologies: Liquid crystal display (LCD),[5] digital light processing (DLP),[6] and liquid crystal on silicon (LCOS).[7] DLP is widely used in the consumer projector market.

China is currently leading in industrial digitalization and Industry 4.0 practices in the home appliance industry. The World Economic Forum has been identifying and recognizing lighthouse factories[8] that represent the best practices of Industry 4.0 globally since 2018. As of October 2022, 114 lighthouse factories were included in the list of best-practice examples, including 42 from China (accounting for 37% of the total count). Midea and Haier each have five lighthouse factories. Industry 4.0 is a continuous development process, and the world is still exploring whether the development of technologies such as humanoid robots will be able to replace human workers, reduce labor costs, and achieve highly efficient automated production. The

[4] The LCD liquid crystal screen driver IC is the main part of the display imaging system. It integrates components such as resistors, regulators, comparators and power transistors, It is responsible for driving the display and controlling the driving current and other functions.

[5] LCD (liquid crystal display), which is constructed by placing liquid crystals between two parallel pieces of glass, with many small vertical and horizontal wires in the middle, and creates an image by changing the orientation of rod-shaped crystal molecules in the presence or absence of the electric current

[6] DLP (digital light processing) is a technology that digitally processes image electrical signals before they are projected.

[7] LCOS (liquid crystal on silicon) is a new type of reflective micro LCD projection technology.

[8] A "lighthouse factory" is a leader in digital manufacturing selected by the World Economic Forum and McKinsey from thousands of factories around the world since 2018.

use of industrial robots and automated devices at existing lighthouse factories has reduced labor costs, but it has notably increased fixed-asset costs. Therefore, lighthouse factories have not been rolled out on a large scale as they have yet to establish a distinct advantage in efficiency over traditional factories.

16.3 Relocation of the Global Home Appliance Industry Chain and Current Challenges From Deglobalization

16.3.1 Driving Forces of Industrial Relocation: Minimal All-In Cost and Local Supporting Facilities

The home appliance industry has undergone a series of relocations. In a world of free trade, companies mainly consider the following factors as they expand production capacity globally.

Minimal all-in Costs: (1) Labor costs: The home appliance industry was relatively labor-intensive before the shift to automated production. World Bank data shows the average monthly salary of workers in Southeast Asia and South Asia was less than 50% of that in China in 2021. The difference in labor costs has facilitated the relocation of the home appliance industry chain away from China, Japan, and South Korea.

(2) Supporting industries: Large amounts of raw materials and components are used by home appliance firms, highlighting the role of supporting industries in cost control, material supply, and upstream—downstream cooperation. China has a wide range of industries, offering abundant resources to support the development of the home appliance industry. To date, Chinese companies still rely on imports of core accessories and components from China when they build production capacity globally.

(3) Transportation costs: Manufacturing and selling large home appliances such as refrigerators, washing machines, and TVs entail high transportation costs, foregrounding the significance of transportation radius, especially for companies seeking capacity expansion overseas. This is the reason why North American home appliance manufacturers generally build their production bases in Latin America, and Western European firms tend to establish their production facilities in Eastern Europe or Türkiye.

(4) Tariff barriers: Tariffs and industrial policies can have a significant impact on the relocation of the global home appliance industry chain. The US imposes tariffs of about 7.5–25% on imports of Chinese home appliances—including ACs, refrigerators, washing machines, TVs, ovens, water heaters, and vacuum cleaners—but applies no tariffs on these products imported from Southeast Asia. As a result, firms have moved some of their small home appliance capacity targeting the US market to Southeast Asia.

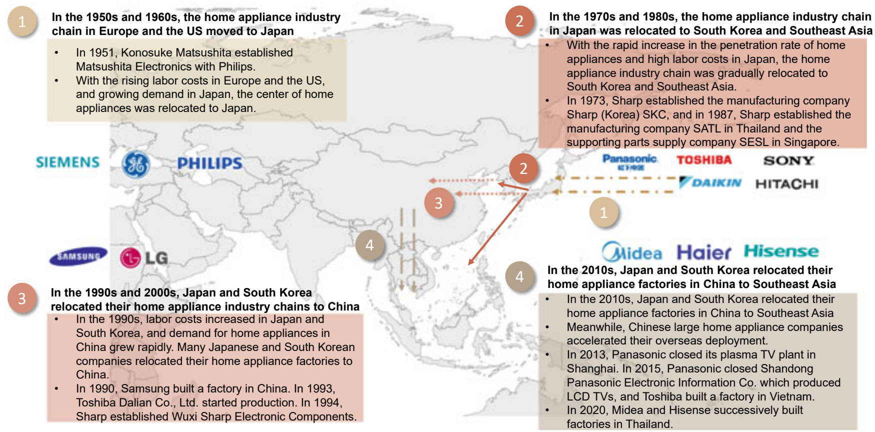

Fig. 16.3 History of global home appliance industry relocation. *Source* Corporate filings, company websites, www.cheaa.com/, Ministry of Natural Resources, CICC Research

Local supporting facilities: The success of a brand lies not only in effective control over costs, but also in the innovation, design, and marketing of products. Companies may have to compromise their minimal all-in cost principles in the stage of brand expansion to better meet local needs and preferences. Consumer demand varies regionally. Therefore, localized production and R&D enable a company to respond to local demand and adjust to specific needs and preferences in a timely manner.[9]

We divide the relocation of the global home appliance industry into four stages (Fig. 16.3). Stage 1: In the 1950s and 1960s, the home appliance industry chain in Europe and the US moved to Japan. Stage 2: In the 1970s and 1980s, the home appliance industry chain in Japan was relocated to South Korea and Southeast Asia. Stage 3: In the 1990s and 2000s, Japan and South Korea relocated their home appliance industry chains to China on a large scale. Stage 4: In the 2010s, China moved further up the global home appliance value chain thanks to factors such as industrial digitalization, market size, and rising market share of domestic brands.

China's home appliance industrial clusters are mostly located in coastal regions, with the remainder in inland regions (Fig. 16.4). Two of China's largest home appliance industrial clusters are situated in the Pearl River Delta (PRD) and the Yangtze River Delta (YRD), where a wide range of products are offered to meet both export and domestic demand supported by well-established facilities. Home appliance industrial clusters have been formed in Shandong, Anhui, and Hubei to meet domestic demand given factors such as transportation radius, and production bases focusing on white goods and black goods have also been founded in Chengdu, Mianyang, and Yibin in Sichuan province and Zhengzhou in Henan province but with

[9] NONG Yunying. "A Study on the Transnational Business Strategy of Chinese Home Appliances Enterprises in Vietnam: A Case Study of Haier's Transnational Business in Vietnam." *Guangxi University* (2021).

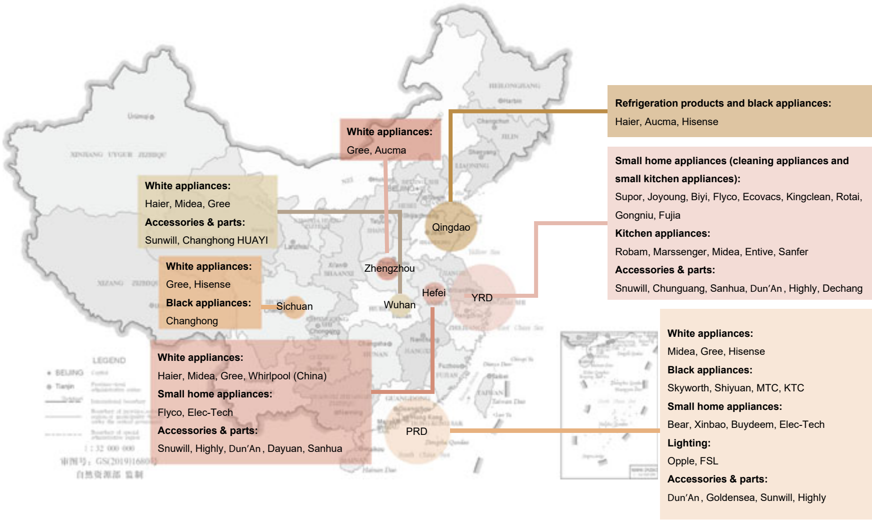

Fig. 16.4 Home appliance industrial clusters in China. *Note* Data as of 2022. *Source* Corporate filings, company websites, websites of local governments, Ministry of Natural Resources, CICC Research

less cluster effect. Export-oriented production capacity has been moving away from the PRD and YRD, where efforts should be made to offset the negative impact of capacity relocation on local employment and economy through industrial upgrading, in our view.

16.3.2 US Tariffs Leading to Relocation of Home Appliance Capacity Away From China

The US is one of the world's largest markets for home appliance consumption. The country's tariff policy has a significant impact on the global distribution of home appliance production capacity, signaling the rise of deglobalization in the home appliance industry. Since 2018, the US has imposed tariffs on Chinese imports, leading companies to move home appliance production capacity out of China. Home appliance manufacturers are relocating some of their production to Southeast Asia and Mexico from China due to tariff differences despite higher production costs in these countries, with the pace of the relocation fluctuating with changes in US tariff policies. We foresee relocation of a majority of home appliance production to Southeast Asia and Mexico if the US maintains high tariffs on Chinese imports.

The US-China trade frictions have prompted home appliance manufacturers to relocate production to Southeast Asia to bypass US tariffs, though home appliance

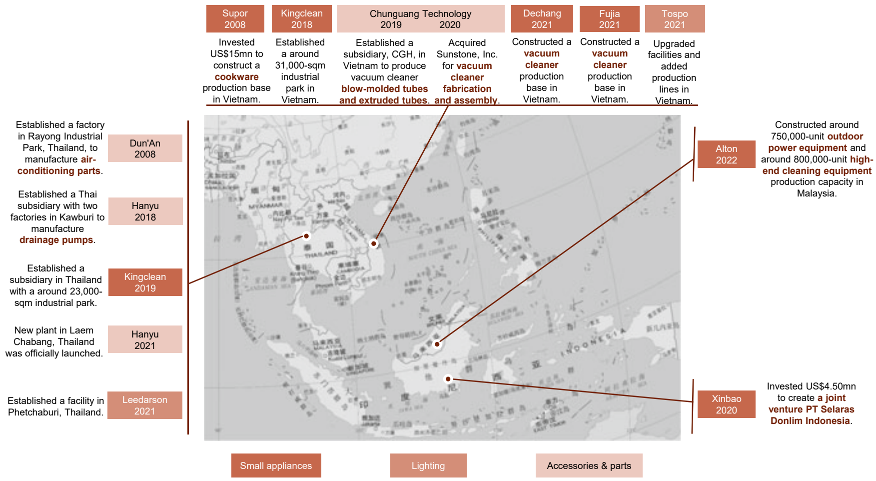

Fig. 16.5 Distribution of Chinese home appliance companies' production capacity in Southeast Asia has yet to form an industrial cluster. *Source* Corporate filings, company websites, Ministry of Natural Resources, CICC Research

industrial clusters have yet to be formed in the region (Fig. 16.5). In the small appliance segment, Supor invested US$15mn in the construction of a cookware production base in Vietnam in 2008, and Dechang Electrical Machinery Made and Fujia Industrial built production bases for cleaning appliances in Vietnam in 2021. Kingclean Electric established industrial parks in Vietnam and Thailand in 2018 and 2019. Xinbao Electrical Appliances Holdings invested US$4.50mn to create a joint venture, PT Selaras Donlim Indonesia, in 2020, and Alton Electrical & Mechanical Industry built production capacity in Malaysia in 2022. Lighting companies (e.g., Tospo Lighting, and Leedarson IoT Technology) as well as home appliance accessories and parts manufacturers (e.g., Chunguang Technology, Hanyu Group Joint-Stock, and Dun'An Artificial Environment) have also established production facilities in Southeast Asia over the past few years. However, it is worth noting that global distribution of small appliance production capacity is affected by US tariff policy, while global distribution of large appliance production capacity is more subject to transportation radius and localized operations.

16.3.3 India: Substantial Market Potential; Market Access Barriers Inducing Relocation of Production Capacity to India

With a large population and a low penetration rate of home appliances, India's home appliance market has become one of the fastest-growing and most attractive markets in the world. Euromonitor estimates that India's home appliance market grew a CAGR of 13% over 2016–2021, outpacing the growth in North America and China. However, foreign investment policy is gradually tightening. In 2014, the Indian government introduced reforms to foreign investment access, abolishing foreign investment permits, and setting up a negative list for foreign investment access, which greatly simplified the investment process. The tax reform in 2019 lowered the corporate income tax in India, and tax incentives were also introduced to support manufacturing industries. However, India's foreign investment policy took a major turn in 2020, imposing special restrictions on investment by entities in countries that share land borders with India. The country initiated review of Chinese investment in 2021, adding to the uncertainty of Chinese home appliance companies' investment and operations in India.

16.4 The Globalization of Chinese Home Appliance Brands: A Long Way to Go

16.4.1 A Long Journey Ahead for the Globalization of Chinese Brands; Overseas Expansion of Large Appliance Manufacturers Started in the 2010s

It took 30 years (1990–2020) for China to develop into a manufacturing power in the home appliance industry, and the country is now facing more challenges in taking its brands global. Large appliance companies in China began to explore overseas markets in the 2010s, and expanded their global presence through establishment of new production facilities and mergers and acquisitions (M&A). Large appliance companies such as Midea Group and Haier have built their own factories around the world considering transportation radius, and strengthened their footprint across the globe through M&A. So far, Chinese large appliance companies have established production bases spanning across multiple regions including Europe, the Americas, Southeast Asia, South Asia, East Asia, and Africa (Fig. 16.6). However, Chinese brands did not demonstrate competitiveness against peers and gain global visibility until after 2020.

Midea Group: The company has an extensive global presence. As of end-2021, Midea had 20 R&D centers and 18 major production bases overseas, covering more than 200 countries and regions. Midea adopts a "China-based Supply for the World + Local Supply" model. The company builds smart manufacturing factories through its Midea Business System (MBS)[10] business management system, automation, and informatization, and its T + 3 business model promotes an efficient business process across the entire value chain.

[10] Midea Business System is a unique business method, exclusive to Midea Group, which helps cut costs and satisfy customers all over the world.

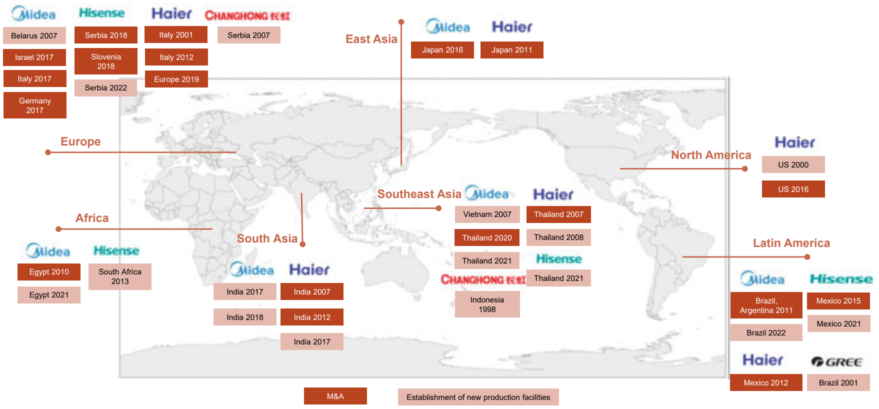

Fig. 16.6 China's large home appliance companies have extensive global presence due to pursuit of geographic proximity to customers and M&A. *Source* Corporate filings, company websites, xinhuanet.com, people.cn, Ministry of Natural Resources, CICC Research

Haier Smart Home: The company aims to build a global brand while expanding its presence through establishment of new production facilities and M&A. As of end-2021, Haier had 122 manufacturing centers and 30 industrial parks around the world, serving 1bn households. As one of the first Chinese home appliance brands to go global, Haier has years of experience in operating factories in Pakistan, India, and Nigeria. It has further expanded global production capacity by acquiring GEA, FPA, Candy, and the white goods business of Sanyo.

16.4.2 Home Appliance Brands Increasingly Global Since 2020

Leading Chinese large appliance brands began their attempt to expand globally in the 2010s, which did not become a trend until 2020 when stay-at-home consumer demand surged after the outbreak of COVID-19. China's home appliance exports grew considerably in 2020 and 2021 as China already took the lead in micro-innovation for many home appliance products and as e-commerce eroded traditional offline channels in Europe and the US. Companies vary in their brand globalization strategies and business models.

M&A: Haier has been widening its global reach through M&A for over a decade, and this has proven to be an effective strategy for large appliance firms given slow development of distribution channels. The company sells products that are locally produced considering transportation radius, and empowers acquired companies with better incentive systems, higher production efficiency, and faster R&D to boost their competitiveness. The acquisition of SharkNinja Technology, a US small home appliance leader, by Joyoung's parent company has helped improve the efficiency of

SharkNinja's supply chain in China and boost its competitiveness in small home appliance markets in Europe and the US by introducing some leading Chinese product technologies (e.g., laser simultaneous localization and mapping [SLAM] algorithm for sweepers).

Product innovation: Roborock is a global leader in laser SLAM algorithms for robotic vacuum cleaners, offering more intelligent robotic vacuum cleaners than iRobot. The market share of Roborock rose rapidly around 2020, supported by Xiaomi's distribution network and solid product performance in Europe and strong sales through Amazon in the US. iRobot, a leading robotic vacuum cleaner manufacturer in Europe and the US, has been losing market share in recent years as its products are less competitive than Chinese brands. In addition, Roborock has a different pricing method for its products compared to some traditional brands, selling products with similar configurations at lower prices in China and at higher prices overseas. With product upgrades, the price of Roborock's highest-end product has exceeded that of iRobot's highest-end product in the North American market.

Cross-border e-commerce: As global e-commerce expands rapidly, some cross-border e-commerce companies such as Anker Innovations Technology have stepped up investment in product R&D with their brands becoming more visible globally. In 2021, Amazon cracked down on illegal cross-border e-commerce operators on its site, resulting in large-scale store closures. Anker Innovations Technology, however, remained intact thanks to its successful transformation.

Production efficiency alone is not enough to push home appliance companies to take their brands global. However, China is now enjoying the fruits of its engineer dividend,[11] with continued product innovation. Combined with channel changes resulting from the impact of e-commerce on offline distribution channels, this has catalyzed the trend of globalization among Chinese home appliance brands. It is worth noting that Chinese home appliance companies still have a long way to go in terms of overseas brand operations.

16.4.3 Thoughts and Implications

Exogenous tariffs have affected the relocation of the global home appliance industry in recent years. However, we should pay more attention to endogenous factors that have been driving the development of China's home appliance industry. It seems to be a natural and plausible choice for Chinese home appliance companies to expand their production capacity and brands globally as they become increasingly competitive in the international markets. Policies could be in place to support Chinese home appliance companies going global, in our view.

Leverage domestic success to cultivate coastal household appliance industry clusters in Southeast Asia. China has formed mature home appliance industrial

[11] Engineer dividend refers to the economic growth potential that can result from a growing population of engineers.

clusters offering a wide range of products supported by a well-equipped industry chain. China can leverage this experience to collaborate with Southeast Asian countries on planning and cultivating new home appliance industrial clusters through trade agreements in a bid to strengthen industrial division of labor and cooperation. The government could take the lead in establishing industrial parks in foreign countries, and encourage Chinese home appliance companies to build factories there on a large scale. Efforts could also be made by the government to seek preferential treatment from local governments for the Chinese companies in the industrial parks, and leverage Southeast Asia's advantages in labor costs and tariffs to benefit Chinese companies.

Cultivate and improve Chinese home appliance companies' localization capabilities in overseas markets to help reduce risks in global expansion. Unlike Midea and Haier, which have rich experience in localization, the majority of Chinese home appliance companies are facing challenges from cross-cultural communication, lack of skilled professionals, and instability in overseas markets due to the lack of experience in overseas operations. Therefore, leading home appliance companies could be encouraged to share their experiences to help others localize their production and sales in overseas markets.

Adopt a multi-tiered capacity deployment approach in response to the relocation of the global home appliance. To strike a balance between capacity efficiency and supply chain security, China can deploy its low value-added production capacity in an efficient manner based on the principles of minimizing all-in costs and ensuring the availability of local supporting facilities, and retain the large-scale capacity that targets the Chinese and some overseas markets and most production capacity for core components.

Achieve a higher degree of import substitution in the home appliance industry chain through continued opening-up. The introduction of advanced technologies of global home appliance leaders through opening up the vast Chinese market marked the beginning of expansion of China's home appliance industry. China continues its opening-up policy to reduce the long-term impact of technological constraints on innovation in the home appliance industry and mitigate the influence of certain policies in major overseas markets. The manufacturing of home appliances involves multiple industries, with core technologies mainly originating from upstream industries. The restraints on China's high-end technology may undermine the innovation of China's home appliance industry.

Turn technological advantages into standard-setting advantages through active participation in the formulation of international standards. International standards lay a technological foundation for global cooperation, and have become a *lingua franca.* The competition in standardization is essentially a competition in core technologies and innovation capabilities. China's participation in international standards setting can help address the trade barriers facing China's exports and holds the key to winning the international markets. It also plays a critical role in promoting advanced technologies of China and enhancing the visibility of Chinese brands. Large home appliance companies may be encouraged to participate in the formulation of international standards and supported to overcome technological barriers, thereby fully leveraging their advantages in core technologies to expand their capabilities.

Chapter 17
Textiles and Apparel—Expanding Production Bases Overseas While Moving Up the Industry Chain

Abstract The textiles and apparel industry has long been a crucial part of China's national economy, driving the country's early development and continuing to be an important industry that generates a trade surplus. The production of textile intermediate goods requires significant investments in capital and technology, while apparel production is labor-intensive. China boasts an extensive, comprehensive textiles and apparel industry chain that shows significant potential for technological advancements in upstream sectors, and it leads the global market in terms of apparel manufacturing efficiency. Given the current global landscape, we believe it is crucial for China to make a steady transition from quantity-oriented textile and apparel manufacturing to quality-oriented manufacturing to ensure its competitiveness in the global economy. This chapter provides a comprehensive analysis of the factors driving the development and transformation of the textile and apparel industry chain, and offers insights to the future.

Changes in the industry chain: Driven by the impact of deglobalization policies, the apparel manufacturing industry is undergoing industrial relocation. The industry may also face new green trade barriers in the future. In response, China is addressing these trade barriers. Although it is currently the world's largest apparel exporter, China's export share has declined since its peak in 2013, with countries such as Vietnam and Bangladesh gaining the lost market share. Throughout history, the textiles industry has undergone five strategic shifts, all driven by the pursuit of cost reduction. In the current phase of industrial transfer, garment manufacturers are expanding to South and Southeast Asia. This strategic relocation is primarily motivated by the attraction of lower labor costs and more favorable tax policies. In addition, China's robust competitiveness in textile manufacturing exports has made it vulnerable to the "decentralization" policies of developed countries.

We believe US-China trade frictions have accelerated the process of industrial relocation. We also think that China's textiles industry is facing significant environmental pressure. In response, over the past decade, China's textiles industry has taken measures such as expanding overseas while also developing textile intermediates and establishing close relationships with Southeast Asian countries along the supply

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chain. China's textiles industry has also made significant progress in sustainable transformation.

Retaining key segments in China and expanding along the value chain to drive development. In our view, investing resources to retain the entire apparel manufacturing industry with the sole purpose of "safeguarding the security of the entire industry chain" may not be economically feasible as the industry has been steadily eroded its comparative advantages. The current relocation phase differs significantly from previous ones, mainly due to China's substantial economies of scale within the industry, which has resulted in only some segments relocating to other countries. We believe China may prioritize retaining the textile intermediates and apparel segments that serve domestic demand. As for the segments that would be relocated, we believe Chinese textile companies have distinct advantages in terms of brand relationships and are adaptable to the ongoing trend of relocating.

As the textiles and apparel industry chain transforms, we believe the main challenges will be a shortage of skilled labor and limited employment opportunities. Within these challenges, however, we see abundant opportunities arising from technological breakthroughs and digital upgrading in key segments. We expect high-value-added upstream segments such as high-performance fibers, functional fabrics, sustainable textiles, industrial textiles, and local brands to be retained in China. We also believe that digitalization and automation will mitigate the labor shortage, create new competitive advantages, and facilitate the cost-effective development of the textiles and apparel industry chain.

Keywords Industrial relocation · Trade barrier · Green transformation · Textile intermediates · Economies of scale

17.1 The Status Quo of the Textiles and Apparel Industry Chain

17.1.1 Textiles and Apparel Industry Plays Essential Role in China's Economy; Consistently Generated a Trade Surplus

Textiles and apparel industry fundamental in China's national economy; growth has slowed in recent years. Following China's accession to the World Trade Organization (WTO) in 2001, its textiles industry experienced rapid development, fueled by abundant labor and land resources. In 2021, domestic textiles firms within a designated scale recorded revenue of Rmb2.57trn. The textile, garment, footwear, and hat manufacturers generated revenue of Rmb1.48trn, accounting for 3% of total revenue of industrial firms within a designated scale. Nevertheless, the growth momentum of the textiles manufacturing industry has been gradually decelerating since 2017, dragged by factors such as economic slowdown, supply-side reforms, and relocation of production capacity.

Around 50% of Chinese textile manufacturing products are exported. This suggests that the textiles industry is still an important export-oriented industry with a trade surplus, although the proportion has declined. In 2021, China's textiles and apparel exports reached US$315.5bn, representing about 50% of production and accounting for 9.38% of China's total exports. This resulted in a substantial trade surplus of US$287.8bn, accounting for 43% of China's total trade surplus. However, both the export share and the trade surplus have declined in recent years.[1]

17.1.2 Textile Manufacturing Industry in the Midstream of the Value Chain; Broad, Comprehensive Range of Segments vs. Other Countries

China's textile manufacturing industry is in the midstream of the value chain. The production of textile intermediate goods requires significant investment in capital and technology, while apparel production is labor-intensive. The textiles and apparel value chain consists of several segments, including upstream raw materials, midstream manufacturers, downstream brands, and distributors. Within the midstream segment, textile manufacturing includes the production of yarn, fabric, and garments. As the industrial chain moves from upstream to downstream, the production model gradually transitions from capital-intensive to labor-intensive. For example, in Luthai Textile's cost structure of the fabric segment, raw materials account for nearly 50% of its operating costs; while depreciation, energy, and manufacturing costs account for more than 30%; and labor costs account for 17%. In the ready-to-wear segment, however, raw materials account for about 53% of operating costs; depreciation, energy, and manufacturing about 12%; and labor costs more than 30%.

China boasts an extensive and comprehensive textiles and apparel industry chain, exhibiting significant potential for technological advancements in upstream sectors. China currently leads the global market in terms of efficiency in apparel manufacturing. Figure 17.1 shows that China is active in all segments of the textiles and apparel value chain, from fiber to garment manufacturing, as well as being the country with the largest scale in each segment. Considering the top 5 firms in each country within each segment,[2] China lags Japan in terms of gross margin in the fiber and yarn segment. This discrepancy is primarily due to industry leaders

[1] Revenue from the textile and apparel revenue has increased in recent years, but the portion of exports and trade surplus have declined because total exports have grown faster than revenue in the textile and apparel industry, particularly in sectors such as the mechanical and electrical products.

[2] This refers to companies from their respective countries. For example, Shenzhou International Group Holdings is considered part of China's garment manufacturing sector, despite having production bases in Vietnam and Cambodia.

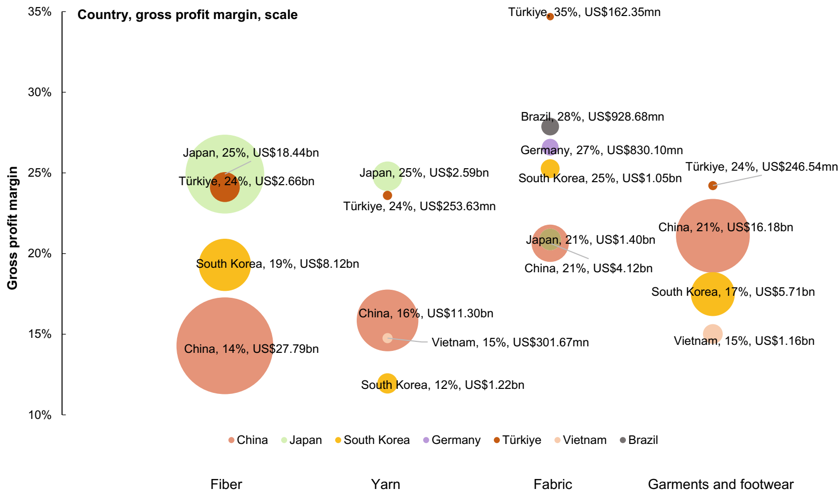

Fig. 17.1 Size and GM of firms in textile and apparel value chain, by country (2021). *Note* (1) Data for each country is taken from the top–five firms in each country in textiles and textile products segments, which may differ from the actual situation; (2) the size of the bubble represents the scale. *Source* Bloomberg, corporate filings, CICC Research

such as Toray Industries and Teijin Limited, which focus on producing high-end fiber materials and expanding their presence into downstream yarns. The versatile nature of fiber materials allows them to be applied in diverse fields such as healthcare and aerospace, resulting in significant value added.

In the fabric sector, the gap in profit margin between China and other countries persists, but is gradually narrowing. This is primarily due to pioneers in the textiles industry such as Germany and South Korea, which have retained manufacturing of fabrics with high gross margins. We believe this demonstrates the potential for manufacturing upgrading in China's textile industry. China leads the world in terms of scale and gross margin in garment manufacturing. We attribute the high gross margin to China's leading efficiency in garment manufacturing thanks to the high quality and effective management of its labor force. For example, per-employee efficiency in China at Shenzhou International Group Holdings reached an impressive 8,000 + pieces/year in 2021, suggesting significant productivity. Moreover, Shenzhou's production bases in Vietnam and Cambodia are also efficient, generating 6,000 + and 4,000 + pieces/year, highlighting the firm's overseas management capabilities.

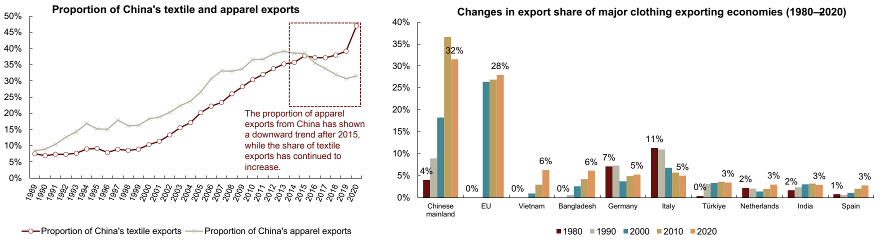

Fig. 17.2 Global apparel exports. *Note* The European Union officially came into existence in 1993, hence there is a lack of data prior to that period. *Source* WTO, UN Comtrade, CICC Research

17.2 Changes in the Textile and Apparel Industry Chain and Security Risks

17.2.1 Driven by Costs, the Apparel Manufacturing Industry is Undergoing Industrial Relocation; the Higher Trade Barriers Are Accelerating Relocation

Chinese garment manufacturers steadily relocating production bases to Southeast and South Asia. China is one of the world's largest apparel exporters. However, China's share of global apparel exports fell 7.6ppt from its 2013 peak to 31.5% in 2020, according to the WTO.[3] Meanwhile, Vietnam, Bangladesh, and India have gained the export share that China has lost, with their export shares accounting for 6%, 6%, and 3% of global apparel exports in 2020. Although the export share in such countries remains modest, the three have consistently gained export market share that China has lost (Fig. 17.2).

The textile industry has undergone five strategic shifts, all driven by the pursuit of cost reduction. When examining the history of textile manufacturing transfers,[4] it is worth noting that large-scale textile manufacturing originated in England during the mid-eighteenth century. The advent of the First Industrial Revolution enabled mass production of textiles, propelling the textile industry into the era of mechanical spinning. Innovations such as flying shuttles notably improved the efficiency of the spinning processes. Toward the end of the nineteenth century, industrial textile demand for cotton had grown rapidly. Given its superior cotton resources and the world's largest and fastest growing consumer market, the US replaced Europe as the world's textile manufacturing center. The US emerged as the driving force during the Second Industrial Revolution, fueled by advances in electrical power.

[3] WTO: https://stats.wto.org/

[4] CHEN Rongfang. "Theory of Industrial Transfer and the Changes of International Textile Manufacturing Center." *East China Economic Management* 12(2005):56–60. LIN Meichun. "Global Transfer of the Textile Industry and China's Countermeasures." *Economy Forum* 11(2007):55–56. CHEN Cai. *Global Economy and Geography*. Beijing Normal University Press, 1990.

Major advances in textile manufacturing in the US that included modern ring spinning machines, automatic looms, and chemical fibers greatly increased productivity and improved the overall quality of textile production. In the mid-twentieth century, Japan undertook the relocation of the textiles industry by leveraging its established industrial bases and cost-effective labor. Moreover, Japan acquired numerous advanced technology patents from overseas and pursued innovative imitation, leading to the widespread adoption of synthetic fiber technology. In the 1970s, South Korea, the Taiwan region of China, and Hong Kong SAR undertook the relocation of the textiles industry driven by their expansive market demand and competitive labor costs. After joining the WTO in the early 2000s, the Chinese mainland established itself as a global manufacturing hub, capitalizing on its abundant labor resources. In recent years, however, apparel manufacturing has gradually shifted to South and Southeast Asian countries due to rising labor costs in China.

Current round of industrial relocation driven by low labor costs, favorable industrial policies in South and Southeast Asian countries. South and Southeast Asian countries boast ample labor resources, with the combined population of 11 Southeast Asian countries and seven South Asian countries reaching 2.5bn in 2021—roughly 32% of the global population.[5]

Most South and Southeast Asian countries' manufacturing industries are still enjoying a demographic dividend. For example, Vietnam and Cambodia had 69% and 64% of the population aged 15–64 in 2021, up 7ppt and 9ppt from 2000. In addition, South and Southeast Asian countries enjoy cost advantages due to more favorable tax policies. Figure 17.3 shows that the corporate income tax rate in the Chinese mainland is 25%, while the Vietnamese government offers a preferential tax rate of 10% for foreign companies that meet certain conditions. Foreign firms operating in Vietnam are also eligible for a tax holiday for the first four years, followed by a nine-year period with a 50% reduction in taxes. The Cambodian government offers preferential policies to attract foreign companies to establish factories in Cambodia, such as a tax holidays for up to six years once the companies start making profits. Vietnam and Cambodia benefit from zero tariffs on textile and apparel exports to Japan, and the tariff on Vietnamese textile and apparel exports to the EU is being gradually reduced to zero, subject to renewal on an annual basis. Apparel products from China, Vietnam, and Cambodia have comparable export tax rates for exports to the US. However, certain Chinese products may be at risk of additional tariffs.[6]

Source Wind, Ministry of Commerce, Ministry of Human Resources and Social Security, Textnet, WTO, Japan Customs, TARIC, US International Trade Commission, National Bureau of Statistics of China, PWC Worldwide Tax Summaries, Tax Guide for Chinese Residents' Investment in Vietnam, Tax Guide on Chinese Residents' Investment in Cambodia, China Textile Go Global Union, Vietnam News Agency, CICC Research.

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[5] Data source: World Bank.

[6] Tariffs on List 3 were implemented in May 2019, followed by List 4 in September 2019. The Office of the US Trade Representative (USTR) introduced exemptions in 2020 and 2022, creating uncertainty.

		China	Vietnam	Cambodia
Water and electricity costs	Average price of industrial water (US$/cbm)	US$0.59	US$0.46	US$0.19 – the water is hard and softening treatment necessary
	Average price of industrial electricity (US$/kWh)	US$0.19	US$0.06–0.11	US$0.15 – electricity supply insufficient; mainly imported from Thailand and Vietnam.
Tax policy	Basic tax rate	Basic corporate income tax rate 25%; VAT 13%. 9%, 6%, 0% – zero VAT on exported goods	Corporate income tax rate 20%; basic VAT 10% – zero VAT on exported goods	Corporate income tax rate 20%, basic VAT 10% – zero VAT on exported goods
	Tax incentives	-	Investment projects in the amount of VND6trn, total revenue of VND10trn/year (or more having more than 3,000 employees after three years of generating revenue) are exempt from the 10% tax rate for the first four years of profit and reduced by half for the following nine years.	Investment projects approved by the Development Council of Cambodia receive special depreciation rates and profit is exemption from taxes for six years; monthly income tax rate is reduced to 1% and profits used for reinvestment are exempt from taxes.
Tariff policy	Exports to the US	HS61 tariff 0–32%; HS62 tariff 0–28.6%; additional tax rate of 7.5%	HS61 tariff 0–32%; HS62 tariff 0–28.6%	HS61 tariff 0–32%; HS62 tariff 0–28.6%
	Exports to the EU	12%	Tariffs on all textile and apparel products gradually reduced to zero	0-12%
	Exports to Japan	HS61 tariff 4.3–9.5%; HS62 tariff 0–11.7%	0%	0%

Fig. 17.3 Vietnam and Cambodia have advantages of low production costs and favorable trade policies. *Note* (1) The utility cost data is based on 2019 dataset; while other data is based on 2021 dataset; (2) only the tariff policies for apparel exports are compared; Harmonized System (HS)Code 61 refers to articles of apparel and clothing accessories, knitted or crocheted, HS code 62 refers to articles of apparel and clothing accessories, not knitted or crocheted

Given US-China trade frictions and other events, higher trade barrier policies are catalysts for relocation of textiles industry chain. The US relies heavily on China for finished textile products. In 2021, the US imported around 25% of its apparel and 43% of its footwear from China. However, this share has been declining in recent years, resulting in countries such as Vietnam, India, and Bangladesh taking the orders that previously went to China. Imports of apparel from China to the US that were included in the fourth round of US tariff increases in September 2019 were subject to an additional 7.5% tariff. Thus, there has been a noticeable decline in US imports from China of textile finished products. UN Comtrade reports that over 2018–2021, the share of apparel and clothing accessories imported from China to the US fell 1ppt, 3ppt, 3ppt, and 2ppt, and the share of footwear, boots, footwear with outer soles, and similar products imported from China to the US fell by 3ppt, 3ppt, 7ppt, and 0ppt. The orders that China has lost have rapidly shifted and relocated to Southeast and South Asian countries. Over 2018–2021, the share of apparel and clothing accessories imported from Vietnam, Cambodia, Bangladesh, and India to the US rose by 3ppt, 2ppt, 2ppt and 1ppt, while the share of footwear, boots, footwear with outer soles, and similar parts imported from Vietnam, Cambodia, and Bangladesh increased by 6ppt, 2ppt, and 1ppt.[7]

[7] Apparel and clothing accessories from HS codes 61–62 and footwear, boots, footwear with outer soles, and similar parts from HS code 64; apparel orders also relocated to countries such as Nicaragua and Pakistan, and footwear orders also relocated to countries such as Germany, Italy, and Indonesia, but the share of the increase was small and fragmented.

17.2.2 China's Textiles Industry Faces Significant Environmental Pressure; Vulnerable to New Trade Barriers

Textiles and apparel industry faces challenges related to energy consumption, carbon emissions, wastewater discharge. *Textile Apparel Weekly* reports that energy consumption in the textiles industry reached 107mnt of standard coal in 2019 – 2.2% of China's total energy consumption and 4.0% of the manufacturing sector. Among the 31 manufacturing industries, the textiles industry ranked No.6, the chemical fiber manufacturing industry was No.15, and the textiles and apparel industry was No.22 for carbon emissions.[8] About 80% of textile wastewater comes from the printing and dyeing segment, while a notable volume of industrial wastewater is generated during the singeing the desizing process. Textile industry wastewater has a high concentration of organic pollutants, the water is darkly colored, and has an elevated alkalinity. The Ministry of Ecology and Environment[9] reports that textiles industry wastewater, ammonia nitrogen, and chemical oxygen demand (COD) emissions in the wastewater, accounted for 6%, 9%, and 14% of total industrial emissions, ranking No. 4, No. 3, and No. 1 among all industrial enterprises in 2020.

We think it is unlikely that China will relocate heavy-pollution textile processes to other regions; introduction of carbon tariffs may create new trade barriers. These factors underscore the need for a green transformation. Countries in South and Southeast Asia face challenges in textile processing due to their underdeveloped utilities infrastructure. Countries in these regions must rely on generators and well water, incurring additional costs to mitigate water and power shortages. Moreover, countries such as Vietnam and Cambodia have implemented stricter environmental protection standards. Based on the National Technical Regulation on Industrial Effluent in Vietnam and the Industrial Wastewater Discharge Standard in Cambodia, the discharge standards for public wastewater treatment systems are more stringent than China's indirect discharge standards.

In Vietnam, for example, the COD limit is set at $\leq$ 150 mg/L, while in Cambodia, it is $\leq$ 100 mg/L. Vietnam and other countries have consistently called for suspending projects that generate significant amounts of pollution. As such, large companies primarily provide support functions to meet the integration needs of upstream and downstream sectors. The EU's Carbon Border Adjustment Mechanism (implemented March 2021) states that all developing countries are subject to carbon tariffs, with the exception of the least developed countries and small island developing states. Relevant studies show that developed countries will benefit once carbon tariffs are imposed, while textiles industries in developing countries will be negatively impacted.[10]

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[8] HAO Jie. "Guangdong Textile to be included in carbon trading market." *Textile & Apparel Weekly* 27(2022):1.

[9] https://www.mee.gov.cn/hjzl/sthjzk/sthjtjnb/

[10] XIE Xuan. *Study on the Impact of Carbon Tariffs on Export Competitiveness of China's Textile Industry*. Diss. Lanzhou University of Technology, 2021.

17.2.3 Chinese Government and Textile Firms Responding to Safety Risks; Production of Textile Intermediates Not Relocated; Green Transformation Has Paid off

Chinese textile companies have to some degree embraced and led relocation of apparel manufacturing. The China National Textile and Apparel Council (CNTAC)[11] reports that as of 2019, foreign investment in China's textiles industry has encompassed the entire industry chain from fiber to apparel, exceeding US$10bn in the form of greenfield investment, equity acquisition, asset acquisition, and joint ventures. For example, foreign companies contribute around 60% to the export value of Vietnam's textiles industry,[12] with China accounting for around 24% of the total foreign investment.[13] China's leading textile manufacturers have been investing in Southeast Asia since 2004. We believe that the garment manufacturing industry in Southeast Asia also faces relocation pressures. Nevertheless, Chinese textile companies have spent almost 20 years establishing localized management capabilities and talent overseas. This positions the firms to adapt to potential relocation as well as guiding and leading the process.

China's textile manufacturers have expanded their overseas investment destinations to more than 100 countries and regions globally.[14] Such destinations include key areas such as Southeast Asia and Africa and aim at exporting production capacity. The industry has extended its reach to Europe, the US, and Australia to gain knowledge in design, technology, and other relevant areas, while also establishing connections with consumers. We believe that by pursuing such strategies, the industry can adapt to long-term changes within the industry chain.

Production of China's textile intermediate goods has not been relocated; relocation of production capacity in garment manufacturing resulted in growth of intermediate goods. China still enjoys strong competitive advantages due to the low proportion of labor costs in the yarns, fabrics, and accessories segments, as well as the industry's high standards for supporting segments within the industry chain. Thus, China's textile intermediate goods segment has not been relocated. Over 2010–2020, the proportion of China's textiles exports to total global exports rose to 47.0% from 30.4%, while the export share of other economies declined (Fig. 17.4).

China's international competitiveness in the higher value-added segments of fibers, yarns, and fabrics has consistently improved YoY. In contrast, Southeast Asian countries such as Vietnam continue to focus on basic sewing and processing. It is

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[11] XU Yingxin. "Foreign Investment in China's Textile Industry." *China Foreign Exchange* 17(2019):3.

[12] https://e.vnexpress.net/news/business/economy/vietnam-businesses-lose-on-home-turf-4681208.html

[13] We estimate the portion of Chinese companies in Vietnam's textile and apparel industry exceeds 24%.

[14] China National Textile Association Institute of Industrial Economics. 20 Years of WTO Accession: Review of Foreign Trade of China's Textile Industry. http://chinawto.mofcom.gov.cn/article/ap/p/202201/20220103236583.shtml

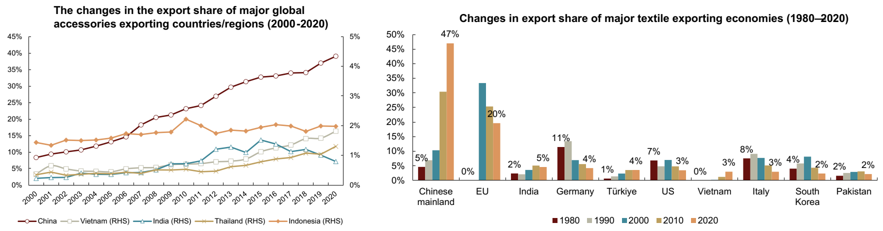

Fig. 17.4 Global textile exports. *Note* The European Union officially came into existence in 1993, hence there is a lack of data prior to that period. *Source* WTO, UN Comtrade, CICC Research

evident that as the export share of garment manufacturing relocates to Southeast Asia, the demand for China's textile intermediates in South and Southeast Asia is increasing accordingly. India and Vietnam still must import about 50% of their fibers, yarns, and fabrics from China, and their dependence on China for textile intermediates is increasing (Fig. 17.5). China, Vietnam, and other Southeast Asian countries have developed a complementarity relationship wherein China produces textile intermediates and the other countries produce garments. In some segments, this relationship resembles a spillover rather than a simple relocation of production capacity.[15]

Policy-driven transformation, elimination of obsolete capacity effective in the green transformation. In response to environmental concerns, China's policies have long imposed requirements on enterprises in the textile industry, including entry regulations, cleaner production practices, energy consumption standards, emission quotas, and wastewater treatment and recycling measures. For example, the number of printing and dyeing enterprises above a designated size in China has continued to shrink to 1,584 in 2021 from 1,922 in 2012. The output of printed and dyed fabrics has also been steadily declining over 2011–2020.[16] The green transformation of the textile industry has achieved positive results thanks to related policies. The CNTAC reports that the energy consumption structure of the textile industry continued to improve over 2015–2020, with the proportion of secondary energy reaching 72.5%.

The industry has also shown improved energy utilization efficiency as the total energy consumption per Rmn10,000 of output value declined 25.5% and the amount of water consumed per Rmb10,000 gross industrial output value declined 11.9% over 2015–2020. The Ministry of Ecology and Environment reports that wastewater emissions, COD emissions, and ammonia nitrogen emissions from China's textile industry declined 37%, 76%, and 90% over 2011–2020. Large companies such as Shenzhou International Group Holdings and Huafu Fashion have expanded into the recycled fiber segment and adopted environmentally friendly processes. They have also embraced green energy solutions such as photovoltaics.[17] We believe

[15] SHI Zhan. *Spillover: A History of the Future of Manufacturing in China.* CITIC Press, 2020.

[16] The large increase in the output of printed and dyed fabrics in 2021 was mainly due to the recovery of the consumer market and the return of orders to China.

[17] Huafu Top Dyed Melange Yarn joined the carbon neutrality acceleration plan to lead industrial green upgrading. https://mp.weixin.qq.com/s/Cpeh4IqcdHHtNCN6X4z8ng

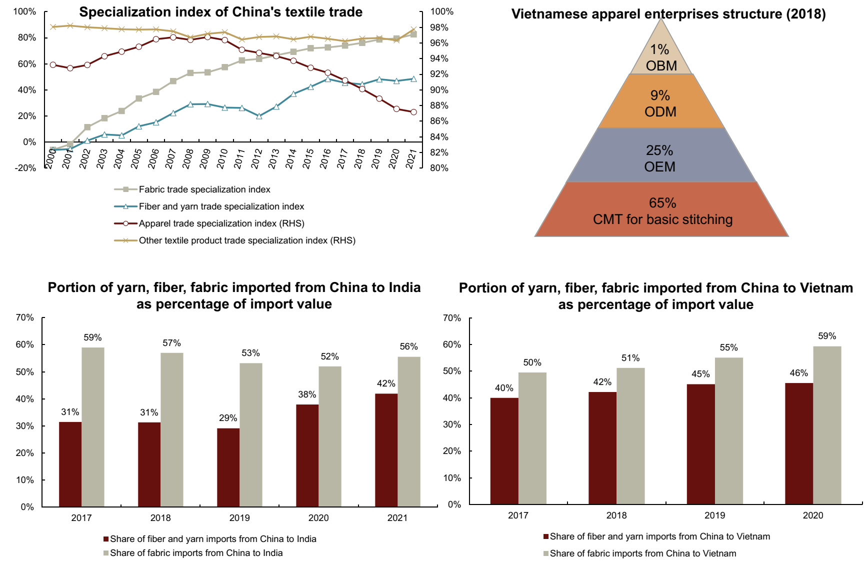

Fig. 17.5 China has significant advantages in textile intermediate products. *Note* (1) The trade specialization index compares the net flow of goods (exports minus imports) to the total flow of goods (exports plus imports); (2) data of fibers and yarns is from HS codes 50–55, fabrics from HS codes 56–60, apparel from HS code 61–62, other textile products (curtains, masks, etc.) from HS code 63; (3) OBM refers to Original Brand Manufacturer; ODM refers to original design manufacturer; OEM refers to original equipment manufacturer; CMT refers to cut, make, and trim. *Source* UN Comtrade, China Textile Go Global Union, CICC Research

these initiatives have the potential to be further extended to small and medium-sized enterprises.

17.3 Evolution and Outlook of the Textiles and Apparel Industry Chain

17.3.1 Relocation of Garment Manufacturing is Unavoidable; Continuing to Promote Retention of Textile Intermediates, Garment Manufacturing for Domestic Demand

Relocation of garment manufacturing overseas is expected. We believe that firms should leverage economies of scale to retain key segments of the industry. The current relocation in the apparel industry is a natural, cost-driven transition. In our view, it is not economically viable to devote resources to preserving industries that are gradually losing their competitive advantages merely to maintain the integrity of the entire industry chain. The pursuit of absolute control of the industry chain would impede the global division of labor and result in significant sacrifices in terms of efficiency and resource utilization, in our view. To navigate the trend in relocation of mature production capacity effectively, we believe it is imperative to allocate additional resources towards comprehensive industry chain upgrades. This strategic approach would allow for relative control over the textiles and apparel industry chain in the most cost-effective manner.[18] Nevertheless, previous relocations have often resulted in the collective relocation of the entire industry chain. However, we believe that China's significant economies of scale in various aspects of supply–demand dynamics will result in a different outcome in this round of relocation. Rather than a complete industry-wide relocation, we envision a scenario in which only certain segments of the textiles and apparel industry are relocated, while key segments are retained in China.

Fully developed industrial system and industrial clusters on the supply side yield numerous hidden cost advantages, facilitate retention of textile intermediate segment in China. Unlike the garment segment, which has lower demand for supporting supply chains, the textile intermediates segment depends on robust heavy industries such as energy and chemicals. For example, Vietnam, which has attracted the most market attention, has an industrial structure dominated by light industry. Thus, its infrastructure – e.g., railways and electricity – is inadequate. The country's chemical fiber industry is also underdeveloped, and the water and electricity supplies necessary for fabric production are unstable. Inadequate support facilities such as accessory factories and pollution discharge systems worsen the situation. Vietnam's weak foundation in heavy industries has become an impediment to development of its light industry, making it difficult for the country to escape the "structural power" imposed by other economies.

This situation involves Vietnam's reliance on upstream technologies from Japan, South Korea, and China, as well as downstream exports to Europe and the US.[19] We believe that the limited strength of heavy industry in countries such as Vietnam is a fundamental reason why Southeast Asian countries have become more dependent on China's textile intermediates following the relocation of the garment industry. While China can continue to promote retention of the textile intermediates segment, it faces a potential risk in the form of trade barriers. ASEAN and China maintain free trade,[20] with over 90% of goods and around 7,000 products enjoying zero tariff treatment. Thus, we believe that any disruption to this free trade arrangement would result in additional tariff costs for China's textile intermediate exports.

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[18] T ANG Yihong, and Z HANG Pengyang. "Improving the Controllability of the Supply Chain of Relocated Industries." *China Opening Journal* 4(2022):7–14.

[19] W ANG Xueying, Z HU Yu, amd J I Xianbai. "Industrial Transfer, International Integration and Concerns about Fragility." *Southeast Asian Affairs*.

[20] The China-ASEAN Free Trade Area was completed in 2010, and the updated protocol took effect in 2019.

Another notable benefit derived from large-scale supply is the advantage of industrial clusters. These clusters facilitate the vertical division of labor and the sharing of intermediate inputs among enterprises, thereby enhancing R&D as well as innovation capabilities through knowledge spillover effects. This in turn fosters an increase in both the variety and quantity of intermediate goods, increasing the added value of such goods.[21] Furthermore, industrial clusters reduce search costs and strengthen transaction efficiency through inter-firm dealings.[22] With more than 30 years of development, China's textiles and garment manufacturing industry has established its presence across the upstream and downstream of the value chain, as well as the ancillary sectors. The majority of intermediate goods can be readily supplied by domestic manufacturers, while several world-class industrial clusters have also emerged.

The CNTAC reports that as of 2020, China had 216 textile industry clusters concentrated in the Yangtze River Delta, Pearl River Delta, Bohai Rim, and Haixi regions, with concentration highest in five coastal provinces – Zhejiang, Jiangsu, Guangdong, Shandong, and Fujian. The number of enterprises above a designated size in these clusters, the revenue of their main businesses, and their profits accounted for 41%, 43%, and 45% of all such enterprises in China's textile industry as of 2020. We believe that a comprehensive industrial system and large-scale industrial clusters effectively embody economies of scale on the supply side. An ultra-large scale supply chain network combines production efficiency with flexibility, thereby diluting fixed costs and costs for technological upgrading, rapid response, and transaction. We believe that these hidden cost advantages will gradually emerge as wages, land prices, and other factor costs rise in countries undertaking industry relocation. Thus, they will serve as an additional advantage for China in retaining the textile intermediate segment.

Paramount economies of scale lie in the market size on the demand side, driven by rigid demand for local brands and locally manufactured goods. China is the largest global consumer market for footwear and apparel, accounting for 25% of the global market share. This impressive figure is supported by a population of 1.4bn. In 2021, China's per capita spending on footwear and apparel reached US$303, suggesting significant upside potential of 2–3 × vs. developed economies such as the US, Western Europe, South Korea, and Japan, where per capita spending was US$1,097, US$678, US$581, and US$524. In terms of brands, driven by China's robust economic strength and growing national confidence, consumer preferences have fueled the rapid rise of domestic brands. Baidu's 2021 *Guochao* Pride Search Big Data Report stated that the amount of attention paid to Chinese brands increased to 75% in 2021 from 45% in 2016, tripling the attention paid to overseas brands. The report also highlights a 56% increase in attention specifically directed towards

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[21] Z HANG Li, and L IAO Sainan. "Local Industrial Clusters and Domestic Value Added by Firms' Exports." *Economic Perspectives* 4(2021):19.

[22] Z HANG Xiaodi. and Z HANG Chi. "Organizational Innovation and Dynamic Comparative Advantage Construction of Industrial Clusters: A Case Study of Shaoxing, Zhejiang Province." *Journal of Zhejiang University* 40.005(2010):126–134.

domestic apparel brands from 2016 to 2021. According to Euromonitor,[23] among the top 20 footwear and apparel brands in China in 2021, the market share of domestic brands rose 0.3ppt YoY, while that of overseas brands fell 0.4ppt YoY, suggesting rising public recognition of domestic brands.

We believe that the rise of domestic brands will increase demand for local manufacturing. For example, 99% of Li Ning's suppliers came from the Chinese mainland in 2021. China's textiles and apparel industry has distinct advantages in international competition due to its initial size and high growth potential in the domestic market, even in extreme scenarios. As a result, we think that factors such as end-market demand, transportation costs, and fragmented supply chains make it difficult for companies – especially domestic companies – to relocate their apparel manufacturing processes entirely outside of China. For example, according to the US National Council of Textile Organizations (NCTO), the output value of apparel manufacturing in the US reached US$10.4bn in 2021. The US is also one of the top 20 apparel exporters globally, strongly suggesting that domestic demand would help retain part of the apparel industry within the country.

17.3.2 Chinese Textile Companies Enjoy Advantages in Brand Relationships That Are Unlikely to Be Disrupted by Industrial Relocation

Relocation of industries does not necessarily mean relocation of companies. We think the concentration of suppliers is the prevailing trend, and Chinese textile companies are increasingly collaborating with brands. Downstream brand customers are focusing on quality rather than quantity of textile manufacturers when selecting textile suppliers as they are influenced by the emergence of fast fashion, growing demand for functional sports products, and the industry's shift to rapid response following COVID-19. The number of original equipment manufacturers (OEMs) for Nike's apparel has significantly declined, while the combined market share of its top five suppliers has consistently risen to stabilize at around 50% over the past three years. Similarly, Adidas witnessed a decline in the number of its athletic footwear and apparel OEMs to 234 in 2021 (vs. 340 in 2014). OEMs at Puma declined to 134 in 2021 from 203 in 2014.

As brand customers reduce their supplier base, demand for stronger cooperation and interaction across the upstream and downstream sectors increases. Notably, brands often require suppliers to engage in targeted fabric development, fostering a positive cycle in which manufacturing and brands align more closely. Thus, we believe that it is crucial to emphasize that the relocation of industries does not necessarily mean a rise in the number of companies from other countries. Chinese firms have built strong and trusted relationships with prominent international brands. For

[23] https://www.euromonitor.com/

example, garment manufacturers on the Chinese mainland – e.g., Shenzhou International Group Holdings – have maintained partnerships with leading international brands such as Uniqlo, Nike, and Adidas for around 20 years. We believe that potential remains for increased collaboration between Chinese mainland firms and leading overseas brands in terms of output and duration in footwear manufacturing. Thus, we believe that such collaboration is unlikely to be disrupted by industrial relocation. In recent years, we have seen brands pushing Chinese apparel manufacturers to expand their global presence in countries such as Vietnam, Indonesia, and Egypt.

17.3.3 Main Challenge in Industry Chain Transformation is Structural Contradiction Between Shortage of Labor Resources and Lack of Employment Opportunities

Near term, labor efficiency in the garment manufacturing industry has peaked, accompanied by steady YoY increase in labor costs. Due to the delicate nature of apparel products, full automation of certain processes remains challenging, resulting in continued reliance on hand sewing in the apparel manufacturing sector. This manual labor component contributes significantly to overall labor costs. However, we believe it is crucial to note that the labor efficiency curve in apparel manufacturing has already reached its apex. For example, Shenzhou International Group Holdings achieved a per capita production output of almost 7,000 pieces of apparel in 2021, but this only reflects a modest 2% increase in the efficiency rate.

Wages of textile workers in Jiangsu province rose more than 10% YoY in 2020 to Rmb63,800, leading to high operating costs for textile firms. Moreover, the age structure of textile workers is imbalanced, with a small proportion of younger workers, and the average age of textile workers exceeding 35, mainly as younger people believe that the textiles industry is low paying and requires overtime. The proportion of highly skilled workers is also low, with around 83% of the workforce having no more than a high school education and 70% of workers lacking certificates of qualification.

We believe the textile industry will play an essential role in ensuring employment stability over the long term. That said, the process of relocating the industry chain and upgrading automated production lines presents structural obstacles to job opportunities. China's textiles industry directly employs more than 20mn people and is intertwined with multiple industries,[24] thereby generating a significant number of jobs and having the potential to increase employment in other industries as well. In the medium-to-long term, we expect the garment manufacturing industry to transform and upgrade by adopting artificial intelligence and smart manufacturing practices, or perhaps relocating to new regions. Such changes likely pose challenges to structural employment – especially in terms of layoffs of older employees and those who have limited skills.

[24] http://www.texleader.com.cn/article/32840.html

17.3.4 Expanding Into High Value-Added Products and Digitalization to Improve Manufacturing Efficiency and Drive the Development of the Industry Chain

History suggests that China must pursue upgrades across the entire industry chain, expand into key products that have high added value. Given the diminishing cost advantages and the impact of deglobalization policies, it is no longer feasible or economically viable to retain the entire textiles and apparel industry chain – particularly the garment manufacturing segment – in China. We believe that the most effective approach entails establishing controllable supply chains in key segments and processes.[25] On the surface, textile manufacturing processes appears rigid and well-established, making it susceptible to homogeneous competition. That said, we believe various production processes and technologies for intermediate textile products can be breakthrough points for vertical upgrading, and such processes and technologies are also key segments and processes. For example, in the fiber preparation processes, it is possible to modify existing fibers to create differentiated, high-performance, and sustainable fibers.

Similarly, spinning processes such as vortex spinning produce yarns are exceptionally fluffy, while Siro spinning enables the production of lighter and thinner yarns. The weaving process facilitates production of ultra-thin, ultra-dense, multi-layered, three-dimensional, and irregular fabrics. Furthermore, the dyeing and finishing process can provide fabrics with various functions such as antibacterial, insect-proof, windproof and waterproof, ultraviolet (UV) resistance, and antistatic. Under the guidance of industrial policies, and throughout history, countries that have relocated the textile industry chain have seen significant structural improvements in high-value-added industries. Such advancements have been facilitated by manufacturing upgrades in materials, processes, and design, as well as the inherent industrial advantages derived from rich natural resources (Fig. 17.6).

We expect high value-added upstream processes – including production of high-performance and functional fabrics, sustainable textiles, industrial textiles, local brands – to remain in China. However, the specific direction of their development will depend on factors such as industrial policies. It is worth noting that the 14th Five-Year Plan for the Development of the Textile Industry highlights certain challenges that China faces in areas such as new fiber material technologies (e.g., carbon fiber, para-aramid, and biodegradable fibers), sustainable manufacturing (e.g., dyeing in non-aqueous medium), and advanced fabrics and equipment (e.g., high-performance fibers and high-speed digital textile printing machines). Moreover, China is pursuing domestic substitution in terms of capital and talent. For example, significant breakthroughs have been achieved in chemical raw materials for a range of high-end textile and apparel products. China has developed bio-based polyamide (PA

[25] TANG Yihong, and ZHANG Pengyang. "Improving the Controllability of the Supply Chain of Relocated Industries." *China Opening Journal* 4(2022):7–14.

	UK	US	Germany	Japan	South Korea	China
Emerging advantage	Introduction of machinery and factory system during the Industrial Revolution	Improved machinery, integrated processes, advantages of cotton production and labor costs	Improved machinery, introduction of US management system and labor cost advantage	Improved machinery, introduction of US management system and labor cost advantage	Labor cost advantage, introduction of advanced foreign technology	Labor cost advantage
Industrial upgrading background	Technological backwardness, intense foreign competition, high production costs, etc.	Slow growth, high unemployment rate, declining domestic enthusiasm to consume, rise of developing emerging markets, etc.	High production costs, insufficient domestic consumption, fierce foreign competition, etc.	Rising labor costs; appreciation of the domestic currency; the rise of emerging textile industrial nations, etc.	Rising labor costs; appreciation of the domestic currency; the rise of emerging textile industrial nations, etc.	Rising labor costs, international trade protectionism
Policies for industrial upgrading	Tariff protection policies; environmental regulations and standards, etc.	AMTEX textile technology development program, a series of free trade mechanisms, etc.	Eliminating outdated enterprises, providing incentives for innovation through patent protection, intellectual property rights system, and technological standards, etc.	Implementing proactive industrial policies, encouraging technological innovation, policies for small and medium-sized enterprises, equipment adjustment policies, etc.	Formulating industrial development policies; formulating education and research policies, increasing investment in education; using technological innovation to promote textile industry structural adjustment policies, etc.	Eliminating outdated production capacity, zero-emission new plans, encouraging technological innovation, formulating policies for "Textile Industry Adjustment and Revitalization Plan", etc.
Legacy	High-end woolen	Raw cotton production, high-tech textiles and clothing	Textile machinery, industrial textiles	New fiber materials, textile machinery, premium garment fabrics	Processing techniques, synthetic fibers, high-performance fabrics	High-performance fibers and fabrics, automated production, global expansion

Fig. 17.6 Major countries that have undergone the relocation of the textile industry and their backgrounds of industrial upgrading. *Source* Junli, Z. and Fangfang, W. Comparison of Textile Industry Upgrading and Implications for China. Journal of Wuhan Textile University, 2016, 29(5), CICC Research

56) and overcome technological bottlenecks in bio-based pentadiamine technology. The country has also established a complete industry chain for the production of polylactic acid. Even without technology spillover from developed countries, we are confident that China has ample talent and financial resources to drive technology upgrading.

Promote digitization and automation to address labor shortages and improve transaction efficiency. If we compare the background of previous industrial relocations with the current one, we see a significant difference: The Fourth Industrial Revolution is characterized by the integration of technology and industry. The new generation of digital, information, and intelligent technologies is facilitating upgrading of the entire textile manufacturing chain, including the improvement of the underlying technological infrastructure (e.g., labor shortages in garment manufacturing can be overcome by automating production). As a result, it changes the traditional conception of comparative advantage and narrows the historical window for latecomers to catch up.[26] This revolution includes development of advanced digital trading platforms that transcend regional and industry boundaries, leading to improved transaction efficiency within the supply chain. When it comes to digitalization and automation, several viable paths are possible. To illustrate low-cost and high-efficiency upgrades, we will look at Huafu Top Dyed Melange Yarn and Shein as examples.

Effective management and maintenance of equipment in the spinning segment, as well as overcoming data fragmentation across different workshops, places significant demands on the workforce. One approach to addressing this challenge is to build intelligent production lines and factories, with the required investment estimated at

[26] XU Qiyuan, and DONG Yan. *Reshaping Global Value Chain Reshaping: China's Choice*. China Renmin University Press, 2022.

around Rmb500mn to Rmb1bn.[27] Color-spun yarn manufacturer Huafu Top Dyed Melange Yarn has adopted a data-driven approach by leveraging Internet of Things (IoT) and the Manufacturing Execution System (MES) to streamline its manufacturing process. In terms of digitalization, the firm's first step is to visualize and digitize internal production machines to facilitate monitoring, management, and feedback during production. The second step focuses on providing cost-effective digital transformation solutions to small and medium-sized factories. With an investment of only around Rmb300,000–400,000, these factories can integrate their production capacity and take advantage of economies of scale within the supply chain network.[28]

On the trade front, Shein plays a role similar to that of Li & Fung, one of the first companies established by Chinese merchants to engage directly in foreign trade. Shein does this by integrating the production capabilities of numerous small factories and connecting them to downstream customers. But unlike the Li & Fung model (characterized by slow turnover and high costs), Shein has embraced digitalization to streamline its operations. Shein has implemented multiple supply-side information systems to quantify design and printing processes, material selection, and worker production. This approach has enabled an efficient operating model focused on small but multiple batches of orders with short delivery periods. Shein can fulfill orders as small as 100 garments and connect directly with end-market consumers, providing them with ready-to-wear garments in only 7–15 days. As a result, Shein has achieved lower inventory levels, a wider range of stock-keeping units (SKUs), and an array of low-cost products. By leveraging its large user base, Shein has taken advantage of its supply chain and created a flywheel effect for its business.

17.4 Thoughts and Implications

17.4.1 Seizing Opportunities From Domestic Industrial Upgrading to Promote Industry Chain Development in Central and Western China

Central and western China play a vital role in meeting domestic demand and stimulating employment. In terms of labor costs, wages in the textile industry in representative central and western provinces such as Henan and Ningxia are higher than those in Vietnam and Cambodia, but are lower than the wages in Jiangsu. As a result, stopping the trend of labor-intensive industries relocating overseas is proving challenging. Nevertheless, central and western China maintains some comparative advantages over the coastal areas in terms of meeting domestic demand and retaining key segments. We expect governments in central and western China to continue to improve the supporting industrial capacity and introducing preferential tax policies,

[27] http://www.wqfz.com/news/newsView/1377

[28] https://mp.weixin.qq.com/s/qQS7DZmzZtIfJww6LHMe0A

and to take advantage of the market economy to further take over part of the textile manufacturing industry chain to meet domestic demand. We expect the transfer of such segments to central and western China to partly alleviate the problems of high labor wages and heavy environmental pressure in the eastern provinces and regions, create some jobs after the transfer of industries, and attract some workers to return to their hometowns.

Technological innovation and talent cultivation are imperative. We emphasize the significance of government guidance in directing firms towards prioritizing the development of key value-added products, including fibers and fabrics. Encouraging the development of high-performance, multi-functional, and versatile textiles is crucial, as is fostering breakthroughs in key technologies. We also believe that it is essential to support the acceleration of digital transformation in the industry, particularly in the apparel sector. This involves establishing seamless connections between the foundational production infrastructure and the advanced digital trading platforms. In addition, we think that the government should establish a robust vocational education system to expedite the training of high-tech talent capable of adapting to the evolving needs of industrial upgrading.

Prioritize energy conservation, emissions reduction, and technology upgrading. We believe the government should support the measures that businesses take to improve energy consumption efficiency and minimize pollutant emissions throughout the chemical fiber, printing, and dyeing industries. This can be achieved by implementing technologies such as heat energy recycling technology and digital printing technology from source processes. We also believe that enterprises should accelerate adoption of green manufacturing practices, including the recycling and production of bio-based fibers, as well as implementation of water- and energy-saving processes in printing and dyeing operations.

Building quality brands and promoting culture are key objectives. We believe the government should foster integration of traditional Chinese culture and contemporary design aesthetics within domestic brands, while harnessing digitalization and direct-to-consumer (DTC) strategies to meet consumer demands and improve marketing effectiveness. We also think it is crucial for the government to encourage large firms to expand into international markets, bolstering their global influence through fashion weeks and exhibitions. In addition, we think manufacturers in the industry should establish a sustainable brand value development system, accelerate the recruitment and training of high-end design talent, and cultivate a diverse range of international and regional brands with their own characteristics.

17.4.2 Embracing Relocation, Exporting Production Capacity, and Connecting International Brands to Globalize

Seizing opportunities presented by relocation of the apparel industry. We believe it is essential to avoid overly aggressive retention policies in mature industries, as this can result in inefficient resource allocation and a decline in national welfare. Instead, we propose that firms embrace the relocation in labor-intensive industries, accelerate digitalization, and assert control over key segments of the industry chain through vertical upgrading.

Promote division of labor and cooperation to export experience. In our view, China should seize the opportunities offered by the Belt and Road Initiative and the tariff benefits offered by the Regional Comprehensive Economic Partnership (RCEP) agreement. This can be achieved by accelerating joint construction of industrial parks and promoting cooperation in Southeast Asia and Africa, thus establishing notable international capacity cooperation projects. In this way, China can create a network of mutually beneficial relationships that facilitate technological expansion between China and these countries. China can also leverage its strengths in overseas management capabilities and brand relationships to make strategic investments abroad and effectively export its experience. This approach allows China to embark on a global journey by deploying capital, technology and management talent.

It is essential for manufacturers to establish connections with international brands to foster leading manufacturers in the industry. Under the trend of brand supply chain concentration and streamlining, we think China should capitalize on its strengths in domestic demand and manufacturing to forge partnerships with prominent international brands—particularly in the footwear manufacturing sector—with the aim of nurturing a cadre of accomplished manufacturers in the industry.

Chapter 18
Investment Amid the Evolution of Industry Chain

Abstract In this chapter, we discuss the implications of the evolution of the industry chain for investments in the real economy and financial market.

The evolution of the industry chain has had profound effects on international investment capital flow. In the era of globalization, China's inbound foreign direct investment (IFDI) and outbound foreign direct investment (OFDI) have grown rapidly. However, as economies gradually shift their focus from efficiency to both security and efficiency in the development of industry chains, international capital flowing in and out of China may also change. In addition to traditional economic factors affecting China's IFDI and OFDI, we also investigate changes in international relations to analyze the trends of international capital flows, and come to the following conclusions:

1. In terms of IFDI, countries and regions that rely heavily on trade with China, those that fit well in China's investment structure, and those with relatively stable or improving international relations may continue to increase their investments in China. Capital-intensive industries have become important directions for IFDI, and the proportion of IFDI in high-end manufacturing industries may continue to increase in the medium-to-long term.
2. In terms of OFDI, the proportion of China's OFDI in countries and regions with sound economic and institutional conditions and stable or improving international relations may continue to increase. Low and medium value-added manufacturing industries which China is offshoring, natural resources industries, and industries in line with the direction of manufacturing upgrading may be the main directions of China's OFDI.

The evolution of the industry chain also has important implications for financial market investment. The interregional relocation of industry chain hubs reflects changes in the comparative advantages of different economies, which affects the sustainability of investment. Based on historical data, we find that the relocation of industry chain hubs is often reflected by the distribution of each country's share

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CICC Research, CICC Global Institute, *The Reshaping of China's Industry Chains*,
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in the global market cap of said industry. Overseas investors prefer industries with comparative advantages, which ultimately leads to wider valuation premiums of such industries. Meanwhile, the position of an industry chain in its own life cycle affects the potential investment returns. Sectors that are in the growth stage or in the second growth stage present larger room for investment in our view. We assess investment opportunities in industry chains and look for those in the growth stage with competitive strength in the global market based on the following measures: technological intensity, structural complexity, and level of standardization. We believe these industry chains can offer high and sustainable investment returns.

Watch effects of economies of scale and the trend of deglobalization. The effect of economies of scale have been fully tapped in the era of the digital economy, but deglobalization may lead to divergence in relative economies of scale among different countries and regions. As a large country, China is relatively better positioned during this process. However, the positive effect of economies of scale may ultimately come to an end, after which global economic growth will become harder, depend more on, and eventually converge to the pace of technological advances. Improving technological innovation capability will become more critical. Against the backdrop of deglobalization, the focus of global industry chain development has shifted from solely efficiency to both efficiency and security. The escalating protectionism may also intensify competition. Increased consideration for non-economic factors may dampen the risk appetite of companies and investors and raise the risk premium of the financial market. This is also a key issue in the industry chain investment.

Keywords IFDI · OFDI · Financial market investment · Deglobalization

In this chapter, we discuss the implications of the process of evolution of the industry chain for investments in the real economy and the financial market.

18.1 Investment in Real Economy: Analysis and Outlook for Industrial Investment Flows From the Perspective of China

The interregional relocation of industry chains is the process of switching directions of corporate investments among regions. Due to certain constraints such as geographical space, international production factors mainly flow in the form of capital. Generally speaking, markets that generate higher profits are more attractive to international capital. In this section, we first calculate China's IFDI and OFDI (excluding the impact from factors such as "tax havens" and "round-tripping capital"), and then analyze the changes in the interregional and intersectoral flows of industrial investments in the Chinese market during the industry chain evolution, and hence predict the trend of future changes.

18.1.1 China's IFDI and OFDI Face New Changes After Rapid Growth

We focus on the following characteristics of changes in the size and structure of China's IFDI and OFDI:

IFDI to China:

1. **China's IFDI stocks have maintained upward trend in recent years, but the pace of growth has slowed.** Data from the United Nations Conference on Trade and Development (UNCTAD)[1] shows that as of 2021, China's IFDI stocks reached about US$2.1trn, increasing 1.9 × compared with that as of 2011. Although OFDI of most countries and regions has declined amid changes in China-US relations and the COVID-19 pandemic, China's IFDI stocks and flows have maintained upward trends, which shows that China remains attractive to foreign companies.
2. **On the level of countries or regions, the Asia–Pacific region is the main source of China's IFDI, while the US and European developed countries' trends of investments in China have diverged.** Hong Kong SAR's share in China's IFDI has long stayed above 20%. Despite a slight decline, Japan's share in China's IFDI has been above 12% over the past decade. Singapore's share has remained at 6–7%. Developed countries such as the US (8%), Germany (5%), and France still accounted for relatively high proportions of IFDI to China in 2020, but the trends have diverged, with the proportions falling for the US and the UK, but rising for Germany and France.
3. **In terms of industry distribution, the proportion of labor-intensive, low and medium value-added manufacturing industries has declined significantly, but these industries still take up high share, while the proportion of service industries has been rising year-over-year.** Low and medium value-added processing and manufacturing industries accounted for more than 30% of IFDI in all industries in 2010, and then shrunk year-over-year and dropped below 15% in 2020, resulting in a decline of the proportion of IFDI to China's manufacturing sectors from 52% in 2010 to 27% in 2020. Given the advantage of China's large market size, the services industry has become a new investment interest for foreign investors. In addition to leasing and commercial services and wholesale and retail, the proportion of investment in scientific research and technological services, information transmission software, and information technology services has also increased. At present, IFDI to China's services industry has exceeded that to the manufacturing industry.

[1] To maintain consistency in the comparison, this comparison includes the overall size of IFDI in each country with round—tripping capital without adjustment. However, in the following section where we only discuss China, we have excluded the impact of round—tripping capital for a clearer description of data for individual economy.

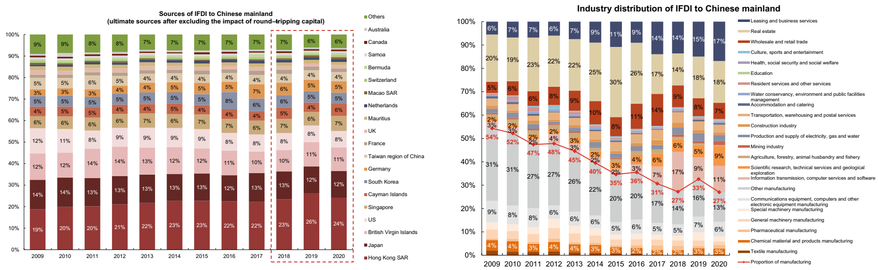

Fig. 18.1 Sources of IFDI to Chinese mainland (ultimate sources after excluding the impact of round—tripping capital) and industry distribution. *Source* UNCTAD, CDIS, Obis, CICC Research

China's OFDI:

1. **China's OFDI has grown rapidly, and OFDI stocks have exceeded IFDI stocks.** In 2021, China's OFDI stocks stood at US$2.6trn, up 5.1 × from 2011, ranking among the highest in the world. However, China's OFDI flows have slowed sharply since 2015 due to multiple headwinds such as the COVID-19 pandemic and geopolitical conflicts.
2. **On the level of countries or regions, the Asia–Pacific region has again become the key destination of China's OFDI.** Given the changes in China's comparative advantage and the need for industrial upgrading, some Asia–Pacific countries or regions (apart from Hong Kong SAR) with rich natural or labor resources such as Australia (10% in 2020), Indonesia, Thailand, and developed countries such as the US, Canada, and Singapore are now the main destinations for China's OFDI (Fig. 18.1). In addition to changes in internal advantages and demand, tariffs and industrial cooperation policies are also key factors affecting China's OFDI. China's overall OFDI in the Asia–Pacific region has increased.
3. **In terms of industry distribution, new-economy industries that represent industrial upgrading and labor-intensive manufacturing industries with low and medium added value are the main directions of China's OFDI** (Fig. 18.2). The proportion of China's OFDI in industries such as scientific research and technology services, information transmission software, and information technology services has increased rapidly, and the proportion of OFDI in manufacturing industries has also expanded. If we assume that China increases OFDI at the cost of reducing domestic investment, the increase in China's OFDI in low and medium value-added manufacturing industries in ASEAN countries may, to some extent, reflect China's offshoring of some low and medium value-added manufacturing industries and labor-intensive industries.

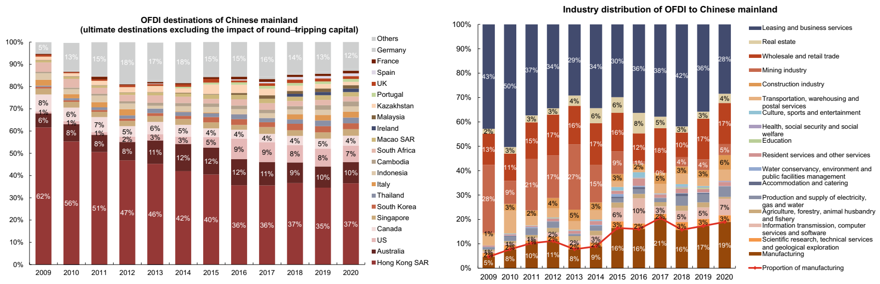

Fig. 18.2 OFDI destinations of Chinese mainland (ultimate destinations excluding the impact of round-tripping capital) and industry distribution. *Source* UNCTAD, CDIS, Obis, CICC Research

18.1.2 Outlook for Future Trends of China's IFDI and OFDI

18.1.2.1 Shift of Focus from Efficiency to Both Efficiency and Security; Changes in International Relations Becoming Increasingly Important to Industry Chain Investment

Focus of industry chain investment has shifted from efficiency to both efficiency and security. In recent years, global geopolitical risks have risen markedly amid changes unprecedented in a century and the impact of the COVID-19 pandemic. Efficiency was the top priority in the globalization era. However, as the world goes down the path of deglobalization, competition between countries has intensified, so has protectionism, which makes it necessary for large economies to consider security while pursuing efficiency. Given the increasing attention to security, international relations will become a non-negligible variable affecting international investment.

Changes in international relations will affect international capital flows and evolution of the industry chain. Looking at the evolution of the international industry chain, we observe that when international relations are relatively amicable, international transaction costs such as tariffs and investment restrictions decline, facilitating cooperation and the development of international industry chains. In this case, the technological gap between developed and developing economies and amicable international relations serve as the twin engines for cooperation in the international industry chain. Taking the development of the mobile phone industry chain as an example, when the penetration rate of smartphones started to rise rapidly in 2010, Chinese companies began to grow rapidly after entering the production and supply chains of leading global companies. However, intensifying international competition has pushed up transaction costs between countries or regions, creating more obstacles to international capital flows, which also prompts the industry chain to shift from globalization to regionalization.

Watch impact of changes in international relations on China's IFDI and OFDI. When international relations become less amicable, countries or regions may impose more restrictions on FDI, which may dampen international capital flows.

In this case, China's IFDI and OFDI can be affected and decline. Our data-based observations indicate that the growth of IFDI and OFDI between China and developed economies is more affected by changes in international relations than those between China and other developing economies.

We think industrial relations between countries may also change amid new trends in international relations. For example, the industry chain relocation from technologically advanced smaller manufacturing economies to large manufacturing economies may evolve into competition with manufacturing industries of large economies due to less amicable bilateral relations, while neutral or friendly countries and regions that have good relations with large manufacturing countries are likely to gain opportunities from the offshoring of large economies.

18.1.2.2 Outlook for China's IFDI and OFDI Trends from Regional and Industry Perspectives

We note that the relatively unfavorable trend of international relations is a new feature against the backdrop of deglobalization, but China's IFDI and OFDI are also affected by various factors such as the economic fundamentals, economic structure, and systems of the source and destination countries and regions. Together with the work of other scholars, we add the following considerations in the analysis of China's IFDI and OFDI.

We need to take into account the trade dependence of the source country or region on China, and how compatible they are with the investment structure in the analysis of China's IFDI. We believe that the higher a country's trade dependence on China, the more challenging it is to significantly reduce investment in China in the face of negative impacts from international relations. Trade dependence refers to the proportion of a country's imports from and exports to China in its total imports and exports. On the other hand, the degree to which the industrial structure of a source country's investment in China matches the direction of evolution of China's industrial structure will also affect the stability of its investment in China. This degree can be measured by the proportion of growth-oriented industries in a country's investment in China. If a source country mainly invests in Chinese industries whose growth is set to accelerate, e.g., knowledge-intensive industries such as high-end manufacturing, its investment in China will likely trend upward as these industries expand. Conversely, investment of a source country into China is more likely to decline if its investment is concentrated in declining industries such as real estate and low-end manufacturing, in our view.

Economic and institutional factors of destination countries need to be considered in China's OFDI. China is a developing country, and China's OFDI has its unique features compared with those of developed countries. Based on existing studies[2,3,4], we synthesize comprehensive indicators from economic and institutional dimensions to build a profile of destination countries or regions. Economic indicators include market size (per capita income), strategic resource endowment (the Human Capital Index published by the World Bank), service sector development (value added of service sector as a percentage of GDP), and communication infrastructure (number of mobile and fixed phones per 100 people). Institutional indicators include economic system, legal system, etc.

Based on the previous discussion, we analyze possible trends in source countries or regions of IFDI and destination countries or regions for OFDI within the traditional analysis framework of factors affecting international investment and factors that take into account changes in international relations. We have come to the following conclusions:

China's IFDI: (1) From the perspective of source countries or regions: We select two indicators to depict the trend of trade dependence and the fit with investment structure. Together with changes in international relations, we believe that those with rising trade dependence on China and a good fit with its investment structures are more likely to become source countries or regions of China's IFDI. Even if international relations are relatively unamicable, these two indicators may partially offset the negative impact on IFDI. Conversely, if both indicators are relatively weak, the proportion of IFDI may decline amid relatively unamicable international relations. **(2) In terms of industry distribution:** After considering China's comparative advantages over overseas industries and the stage of evolution of the industry chain, we believe that capital-intensive industries are becoming the main targets of IFDI. In the medium-to-long term, high-end technology-intensive industries in which China has clear competitive advantages may also gradually become the main areas of investment for foreign investors, while low and medium value-added manufacturing industries and fixed asset investment-related industries may become areas where the proportion of IFDI may decline.

China's OFDI: (1) From the perspective of destination countries or regions: We select economic and institutional indicators to portray destination countries or regions, and analyze them together with factors related to changes in international relations. If the economic and institutional conditions of destination countries or regions are more favorable, China may not substantially reduce OFDI when international relations become less amicable since these markets remain attractive. However, if the economic and institutional conditions of destination countries or regions are less favorable and international relations deteriorate, China may first reduce OFDI into such countries or regions. **(2) In terms of industry distribution:** Considering

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[2] REN Xiaoyan, and YANG Shuili. "Empirical study on location choice of Chinese OFDI." *China Economic Review* 61 (2020): 101428.

[3] ZHANG Xiaoxi, and Kevin Daly. "The determinants of China's outward foreign direct investment." *Emerging markets review* 12.4 (2011): 389-398.

[4] KANG Yuanfei, and JIANG Fuming. "FDI location choice of Chinese multinationals in East and Southeast Asia: Traditional economic factors and institutional perspective." *Journal of world business* 47.1 (2012): 45-53.

		IFDI	
	Countries	Foreign investment in China increased	Foreign investment in China decreased
OFDI	China increased investment	Economic and institutional conditions are favorable for Chinese investment, such as relatively large market size of the host country, rich resource endowment, high technology level, or good domestic institutional environment. High trade dependence on China, investment in China's growth industries accounted for a high proportion in total investments. Bilateral relations are improving or stable, fewer restrictions on investment in China.	Economic and institutional conditions are favorable for Chinese investment, such as relatively large market size of the host country, rich resource endowment, high technology level, or good domestic institutional environment. Low trade dependence on China, investment in China's growth industries accounted for a small proportion in total investments. Bilateral relations with China are stable or increasingly tense, and there may be some restrictions on investment in China.
	China decreased investment	Economic and institutional conditions are not favorable for Chinese investment, such as limited market size of the host country, weakening resource endowment and technology advantages compared with China, or unattractive domestic institutional environment. High trade dependence on China, investment in China's growth industries accounted for a high proportion in total investments. Bilateral relations are improving or stable, and there may be some restrictions on investment in China.	Economic and institutional conditions are not favorable for Chinese investment, such as limited market size of the host country, weakening resource endowment and technology advantages compared with China, or unattractive domestic institutional environment. Low trade dependence on China, investment in China's growth industries accounted for a small proportion in total investments. Bilateral relations are increasingly tense, more restrictions on investment in China.

		IFDI	
	Industries	Foreign investment in China increased	Foreign investment in China decreased
OFDI	China increased investment	The industry is mature in the host country, which has comparative advantages. The investment country has not established complete control over it, and international competitiveness is strong. Industry representatives: High-end services such as scientific research and information technology, production and supply of electricity, gas and water.	The industry is still in the standardized stage. The host country has lost control of the industrial chain in China, and the international competitiveness is relatively average. Industry representative: Low-end manufacturing.
	China decreased investment	The industry is mature. The host country still controls the industrial chain in China and has comparative advantages. Funds can flow into China, but under the influence of institutions, investment is difficult. Industry representatives: Mining, leasing and business services, accommodation and catering and other low-end services.	The industry is still in the standardized stage, and is at the end of life development, which does not match the main trend. The investment country is losing control, and the international competitiveness is weak. Industry representatives: Real estate, construction.

Fig. 18.3 Forecasts on trends of China's IFDI and OFDI. *Source* CICC Corporation Research

the growth trends and the structural changes of industries in China and destination countries or regions, China may increase OFDI in low and medium value-added manufacturing industries under the trend of optimizing industrial structure and offshoring of these industries to overseas economies. On the other hand, areas related to the fundamentals of economic development and industrial upgrading such as resources and technology manufacturing may also account for a higher proportion of China's OFDI. Sectors in which China's OFDI may decline mainly include fixed asset investment-related sectors such as real estate, construction, and mining (Fig. 18.3).

18.1.2.3 Impact of International Investment Flows on Evolution of Industry Chain

International capital flows have a major impact on evolution of global industry chain. When an industry receives concentrated investment from foreign investors due to its comparative advantage at the production level, it means that the industry has sufficient development resources, and can gradually form economies of scale while expanding, achieving cost reductions, and becoming the global industry chain hub. This is clearly reflected by the sharp increase in China's IFDI and China's path to becoming "the world's factory". However, if FDI is based solely on consumption potential and only non-key links such as sales are transferred, it is not considered as relocation of industry chain hubs.

The new trend of international investment may mean that a growing number of China's mid-range and high-end manufacturing industries are likely to become global industry chain hubs. Based on our forecasts on China's IFDI and OFDI trends, we believe China may continue to play an important role in some capital-intensive industries, and a growing number of mid-range and high-end manufacturing industries in China may gradually gain competitive advantages and become global industry chain hubs. On the other hand, China has offshored some low and medium value-added manufacturing industries with weakening advantages or diseconomies of scale to overseas emerging markets, implying that such emerging markets are gradually forming new industry chain hubs. In this process, changes in international relations in the deglobalization era may have a negative impact on international investment. For example, although developed countries' reduced investment in China may not alter the existing trend, the formation process of an industry chain hub in China may decelerate.

18.2 Investment in Financial Markets: Opportunities and Risks Amid the Evolution of Industry Chain

On the basis of our analysis of the real economy, this section will discuss the implications of the relocation of industry chain hubs and stages of industry chain development for capital market investment, as well as the possible opportunities and risks.

18.2.1 Implications of Industry Chain Relocation for Capital Market Investment

China upgrades industrial structures broadly amid the interregional relocation of global industry chains. After 2010, China's manufacturing industry began to evolve from low value-added, less-technology-intensive, low-quality, and weak brands, typically in household appliances, technology hardware, and machinery. For example, the market share of Chinese smartphone brands in the domestic market was relatively low in 2010. However, as some Chinese manufacturers of smartphone components began to enter international supply chains and a number of companies became internationally competitive, Chinese smartphone equipment manufacturers caught up with the global market thanks to increases in both supply and demand. Compared with the traditional mobile phone era, China has become the global mobile phone value chain hub in the smartphones era and has gradually moved up along the value chain from low value-added assembly to high value-added design, branding, and marketing.

The formation of value chain hubs means that financial market investment is more sustainable. Relocation of an industry chain hub to a certain country means that this country enjoys comparative advantages and tends to obtain more resources for development. On the one hand, overseas competitors can be prevented from entering the domestic market, reducing the risk of competitive disadvantage or deterioration of the competitive landscape. On the other hand, overseas markets can drive new growth in demand after domestic demand peaks. Therefore, for capital market investors, industry chains that are globally competitive and may gradually become global hubs are likely to have higher perpetual growth rates, and returns from investments tend to be more sustainable. Specific capital market features include:

1. **Relocation of industry chain hubs leads to a rising proportion of listed companies of related countries or regions in the global total market cap.** For example, the US, Germany, and Japan became global leaders at different stages in the era of fossil fuel vehicles. In particular, Japan and Germany have been competing fiercely in vehicle exports since the 1990s. Toyota's focus on the core vehicle segment, modularization, and professional outsourcing have replaced Ford's vertical integration as the global mainstream vehicle production model. Japan and Germany also had much larger market shares in the global market caps of the auto value chain than other countries during this period. However, as global and Chinese alternative fuel vehicle (AFV) value chains began to grow and replace fossil fuel vehicle value chains since 2015, China's AFV industry grew rapidly since 2019, with exports of passenger vehicles, auto parts, and automotive batteries rising substantially and approaching those of Japan. Meanwhile, the Tesla model has gradually become the new production model of automakers. In this context, China and the US have exhibited the trend of becoming the new hubs of the global auto industry chain. The proportion of the US and China's auto value chains in the global total market cap has been rising since 2015 and increased substantially after 2020. The US and China now account for over 50% of the global market cap of the auto industry chain (Fig. 18.4).
2. **International investors usually prefer fields with strong or improving international competitiveness.** Overseas investors tend to invest in globally competitive industries based on their knowledge as they are not necessarily familiar with local industries when making investment decisions in different markets. For example, starting from 1983, foreign investors increased their exposure to the semiconductor and other electronics industries in which the Taiwan region of

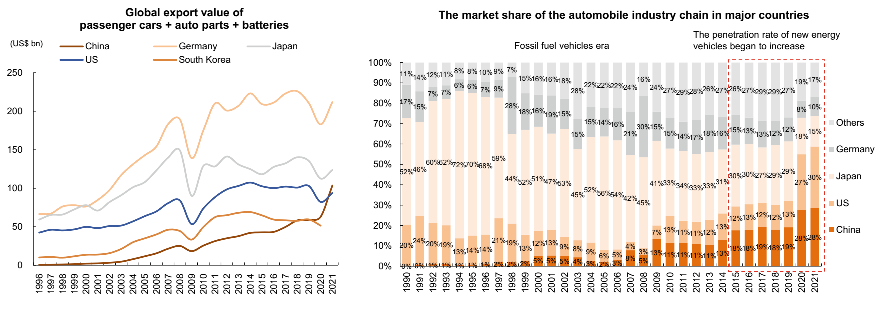

Fig. 18.4 As the era of fossil fuel vehicles transitions to the era of alternative fuel vehicles, the gradual shift of the automobile industry chain hubs to China and the US is also reflected in their proportions of global stock market caps. *Source* UN Comtrade, CICC Research

China enjoys strong advantages. Since 2000, their exposure to these industries has increased significantly, and these industries accounted for a much higher proportion of overseas shareholdings than other sectors. China's high-end manufacturing industry exhibited strong resilience after US-China trade frictions arose in 2018, and foreign investors also significantly increased their exposure to high-end manufacturing industries in China such as the alternative energy and photovoltaic value chains.

3. **Valuation premium widens amid relocation of value chain hubs.** On the basis of improving the sustainability of value chain investment and increasing recognition from global investors, the formation of industry chain hubs often leads to valuation expansion. Judging from the experience of Japan's semiconductor industry catching up with that of the US in the 1980s, the valuations of Japan's top five semiconductor companies are positively correlated with Japan's share in the global market and its comparative advantage over the US. When Japan's semiconductor market share rose and exceeded that of the US, the overall valuation of Japan's semiconductor industry expanded. When Japan's market share peaked and then fell in the late 1980s, the valuations of related companies generally fell to normal levels. Valuations of China's high-end manufacturing industry have also exhibited similar characteristics. As China's auto value chain becomes more competitive globally, the valuations of Chinese auto parts and electric vehicle batteries have risen markedly compared with overseas leaders since 2020.

Differences in global competitiveness may lead to diverging market performance of different industry chains in China. The above-mentioned market characteristics during the relocation of global industry chain hubs have been reflected in important industries both globally and in China. Looking ahead, we expect China to replicate similar investment opportunities in globally competitive industry chains and enjoy more global investor attention and valuation premiums.

18.2.2 Implications of Stages of Industry Chain Development for Capital Market Investment

The life cycle of the industry chain is another indispensable factor that should be considered. Even if China enjoys global comparative advantages in the manufacturing link of an industry, the global competitiveness may not always be able to offset the loss from demand contraction, and investment in such an industry is unlikely to generate returns if the industry itself faces the risk of shrinking global demand or being replaced amid technological advances. Therefore, in addition to global competitiveness, the stage of development of an industry is also a key factor to consider in investment. We use the life cycle of an industry to illustrate this, which may determine the potential returns of financial market investment.

Optimization of the division of an industry chain's life cycle. Traditional industrial cycle theory divides an industry into four stages: Introduction, growth, maturity,

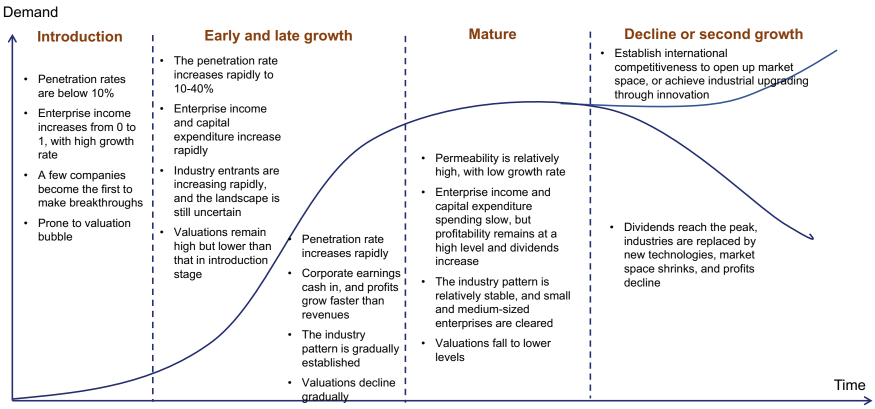

Fig. 18.5 Stages of industry chain development are reflected in the life cycle of industries. *Source* Wind, CICC Research

and decline. The growth stage attracts the most attention. We further divide the growth stage into early and late stages. In the early growth stage, companies tend to see high revenue growth (faster than profit growth), and capex and R&D expenses still account for a relatively high proportion of revenue. In the late growth stage, companies gradually switch from high revenue growth to high profit growth as economies of scale emerge and the competitive landscape improves, and the proportion of capex may be lower than in the early growth stage. Some industries may directly enter a recession due to shrinking demand after the maturity period, but some industries may leverage global competitiveness to expand overseas markets or create new demand through product supply innovation, thereby achieving a second growth curve (Fig. 18.5).

Changes in the industrial life cycle often depend on the macro environment. China's stock market displayed structural changes around 2010, with new-economy sectors significantly outperforming old-economy ones. The reason behind this is the change in the stage of China's economic growth. From 2000 to 2010, China was in a stage of rapid growth in fixed asset investment and capacity expansion. Nominal fixed asset investment growth averaged more than 20% per year during the period, which helped China become the world's largest consumer of raw materials, and also drove rapid earnings growth in the raw materials sector and a bull market in commodities. After 2010, China's fixed asset investment growth began to slow due to overcapacity in many sectors, while consumer markets and sectors that support consumption upgrading continued to expand steadily. Therefore, resource sectors that were considered growth stocks in 2005–2007 began to be considered as mature or even declining sectors after 2010, while sectors related to consumption and industrial upgrading became growth sectors.

18.2.3 Shift of Focus From Efficiency to Security and Non-economic Factors May Lead to a Higher Risk Premium

Globalization trend is relatively positive to investment in China's industry chain. In the era of globalization over the past four decades, China has improved efficiency under international economic and trade cooperation, and its economic strength has increased rapidly, while its enterprises come to play an increasingly important role in the global economy. Although the stock market stagnated and the average valuation declined in the early stage of economic transformation, high-quality companies representing the direction of China's industrial upgrading and consumption upgrading still generated lucrative returns as the number and proportion of non-state-owned enterprises increased. These companies attracted attention from long-term institutional investors, and realized rising average valuation and falling average risk premium.

Shift of focus from efficiency to security may mean rising market risk premium. Under the trend of deglobalization, the shift of focus from efficiency to both efficiency and security is another major feature in the development of the global industry chain and the international division of labor, which is a new issue facing investment in the industry chain. Increasing protectionism in different countries and regions may mean more government regulation and more non-economic factors affecting the operation and layout of the industry chain. This may significantly increase the uncertainty faced by enterprises and investors, and reduce risk appetite, which may be reflected in the capital market by rising risk premium, requiring higher risk compensation for the increase in non-economic factors.

18.2.4 Outlook for Opportunities and Risks in Industry Chain Investment

18.2.4.1 The Global Competitiveness of China's Industry Chain Comes from Four Advantages, and the Country's Large Market Size is the Most Fundamental One

The global competitiveness of the industry chain and its life cycle are two aspects for analyzing industry chain investment, as well as dimensions that need to be considered when analyzing long-term investment opportunities. In particular, the global competitiveness of China's industry chain is relatively unique and closely related to China's own advantages.

Large market size remains the most important advantage on which China's industry chain relies to achieve global competitiveness. Based on our analysis in the previous chapters and sections, we believe that China's industrial development has four advantages, i.e., large market size, large and complete industry chain, sound infrastructure, and large amount of talent. Most developed and developing economies do not have all of these advantages. The advantage of large market size is the most fundamental factor. The large-scale production brought about by industrial transformation, together with China's unprecedented single large market, can give full play to the unprecedented large scale of production. This is the most noteworthy aspect of China's industrial upgrading. Large market size brings about large-scale production and demand, creating economies of scale and ultimately driving down unit production cost. This is also an important reason why most Chinese manufacturing industries have established global competitive advantages.

Economies of scale may play more important role than in the past along with the improving productivity. Economies of scale underwent three stages along with social development: (1) In the traditional agricultural society, land was the most important factor of production, and the economies of scale reflected by land use is negligible. The differential ground rent theory may be a reflection of the lack of economies of scale in land; (2) With the advent of the industrial society, economies of scale gradually emerged along with changes in the factors of production after machines became the main factor of production. The marginal cost of industrial production declined with the increase of scale within a certain range. However, such economies of scale have limits. Costs may rise if production exceeds a certain level, which may lead to diseconomies of scale. (3) In the digital era, data has become an important factor of production. Compared with the industrial economy, the economies of scale brought by data have been improved further. As platform companies' use of data has almost no marginal cost, and the factors of production are becoming increasingly public, they have achieved economies of scope through network effects. Overall, as factors of production are gradually showing attributes of public goods, the corresponding economies of scale of social production also become stronger, and the whole society will benefit from the improvement of production efficiency. For economies with large market size, their economies of scale may also be more fully unleashed as factors of production change. From the perspective of capital market investment, industry chains with stronger economies of scale tend to have stronger profitability and continue to maintain a certain earnings growth rate after they grow to a large scale. The corresponding average valuation and the ceiling of stock market cap may also be higher than in previous eras. For example, US technology leaders have maintained high earnings growth and profitability after reaching a large scale in recent years. Their market cap as a percentage of the US stock market is much higher than that of stocks in the past, and their average valuations are also higher than those of leading companies in the industrial society.

Structurally, China's large market size may still benefit from improving economies of scale amid deglobalization. In the era of globalization, all economies have benefited from strengthened economies of scale, and even smaller economies can benefit from economies of scale through free trade. However, the deglobalization trend is rising and the pursuit of efficiency improvement is no longer the solitary goal. Deglobalization has hindered countries from taking advantage of the international market, forcing them to rely more on the initial economies of scale formed in their domestic markets before participating in international competition. As a result, large economies are more likely to trigger economies of scale than smaller ones and enjoy new advantages in economies of scale. In this context, even if global cooperation and rising transaction costs result in global economies of scale declining or being lower than the trend in the era of globalization, China has the potential to tap the economies of scale of a large economy given its large population and market. China's economies of scale and structural position may actually rise compared with other economies. For investors, China's efforts to leverage its economies of scale to develop a knowledge-based economy may help some industries become global industry chain hubs and form new China-centric industry chains, which may be beneficial to the proportion of market cap, fund flows, and relative valuations of China's industry chains.

The large market size complements other advantages, giving China a unique position in the world. (1) China's relatively complete industry chain and industrial clusters are important advantages in attracting both multinational companies and domestic companies. China's presence across the entire industry chain is based on market demand. Emerging economies and some developed economies with smaller aggregate sizes do not have this advantage. (2) Large market size supports large-scale infrastructure construction. China has advantages in high-speed railway infrastructure and internet coverage, enabling China to improve efficiency and reduce costs in logistics and online channels. (3) The country's massive talent pool and growing R&D investment enable China to shift from a country with a very large population to a country with a large number of engineers. China continues to enjoy cost advantages given its well-educated labor force, laying a foundation for industrial upgrading and moving up the value chain. These four advantages enable China to enjoy a unique position in the global industry chains. Even if the labor cost advantage on which China relied in the past gradually fades, China's dominant position in the industry chain is unlikely to be replaced.

18.2.4.2 Investment Opportunities in the Chinese Market Based on the Global Competitiveness of the Industry Chain and the Industry Life Cycle

Based on the current characteristics of China's development, we believe that industries with the following characteristics can better leverage China's four advantages, and are likely to be the first to establish global competitiveness and become global industry chain hubs:

- **Industries with mid-to-high technological intensity.** Industries with a certain level of technological intensity can take full advantage of the cost advantage of China's well-educated labor force, and proactive industrial policies can help eliminate the bottleneck of industrial development, giving China a distinct advantage over other developing economies. However, compared with developed countries in Europe and the US, China's manufacturing industries mainly rely on large-scale capex, and R&D investment is insufficient. At present, China is still lagging in cutting-edge technologies, and it is unlikely for China to gain an advantage in some industries that are still in the early stages of innovation and have high technological intensity in the near term. If we use the R&D expense ratio to characterize the technological intensity of China's industry chain, the areas in which China has an advantage are mainly those in the mid-to-high percentiles of R&D expense ratios.

- **Industries with a relatively complex industry chain.** China's large and complete industry chain has effectively reduced the procurement and logistics costs of enterprises and shortened the response time to changes in demand and technologies. This means that industries with complex industry chains can enjoy more comprehensive support in China, while most overseas economies may find it difficult to accommodate such industries. We use the input–output table to build a model of the end-product demand network to calculate the length of each industry chain so as to portray the complexity of the industry chain. The longer the industry chain, the more competitive advantage China has in the global market. If the length of a value chain is above the 50th percentile, we say China has a competitive advantage in this industry.
- **Industries with highly standardized products.** Industries that can standardize production, have low product differentiation, and are highly tradable can take full advantage of China's large market size for large-scale production and reduce costs to the lowest possible level. For example, auto, household appliances, and most machinery and equipment are relatively standardized, while production for manufacturing industries such as food, apparel, and furniture are difficult to standardize due to the large differences in consumer preferences. Therefore, manufacturing industries with a high degree of product standardization are more likely to take full advantage of China's large market and become highly competitive in the future.

Based on our analysis in the above three dimensions, we believe that China's industry chains that enjoy competitive advantage or are likely to become more competitive globally mainly include auto manufacturing, electrical machinery and equipment manufacturing, general equipment manufacturing, transportation equipment manufacturing, special equipment manufacturing, and computer, communication, and other electronic equipment manufacturing.

On the other hand, industry chains with global competitive advantages also need to be in a favorable position in their own industrial life cycles. Based on the previous dynamic and static analysis of the life cycles of various industries, we identify the life cycle stages of industries with a focus on whether industries are in the growth stage and whether they have a secondary growth curve after entering the maturity stage. (Fig. 18.6).

Based on the Three Criteria of Horizontal Comparative Advantage of Each Industry Chain and the Position of the Vertical Industry Life Cycle, We Divide Each Field into Four Quadrants:

1. **Industries offering more investment opportunities:** Such industries will remain as competitive as or become more competitive than they are now in the global market, and their life cycles are consistent with the macro environment and are at the growth stage. These industries are more likely to generate high and sustainable returns.

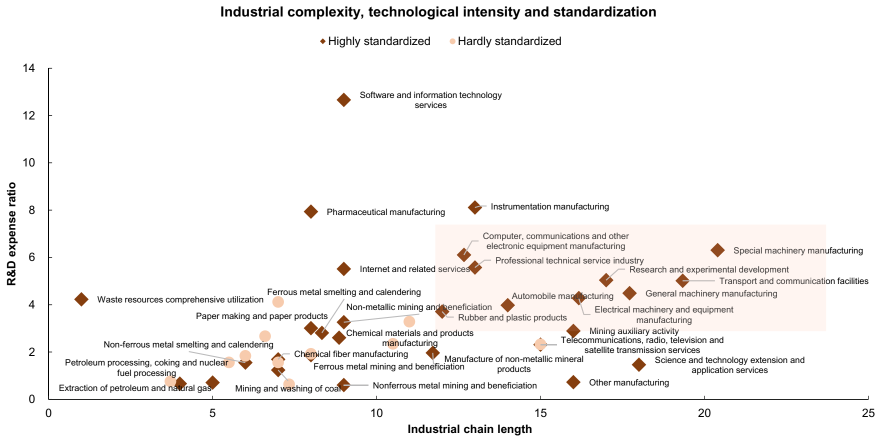

Fig. 18.6 China's industry chains with strong competitiveness in the global market in terms of industrial complexity, technological intensity, and standardization. *Note* R&D expense ratio is based on the average figures over 2019–2021. *Source* Wind, CICC Research

2. **Industries offering possibly more investment opportunities while presenting more uncertainties:** While it may be difficult for industries to develop strong competitiveness in the future or their competitive advantages remain weak, the industry life cycle is in line with the macro environment and is at the high growth stage. Although such industries may have high potential returns, their long-term outlook remains uncertain.
3. **Industries offering selective investment opportunities:** Industries will remain highly competitive in the global market or their competitiveness will improve further in the future. However, these industries are close to the maturity stage. It is also worth investing in if their global competitiveness is used to open up new market space and achieve a secondary growth curve. However, if these industries do not conform to the macro environment and enter the recession stage, they may offer relatively few investment opportunities.
4. **Industries offering relatively few investment opportunities:** If industries are unlikely to form strong competitiveness or its competitive advantages are weakening, and are unlikely to create a secondary growth curve after entering the maturity stage or recession stage, there may be relatively few investment opportunities in such fields.

Based on the above analysis, we have identified a number of sectors presenting more investment opportunities, including photovoltaics, lithium-ion batteries, photovoltaic equipment, lithium-ion battery equipment, alternative fuel vehicles, auto & parts, pharmaceutical outsourcing, and alternative energy materials (Fig. 18.7).

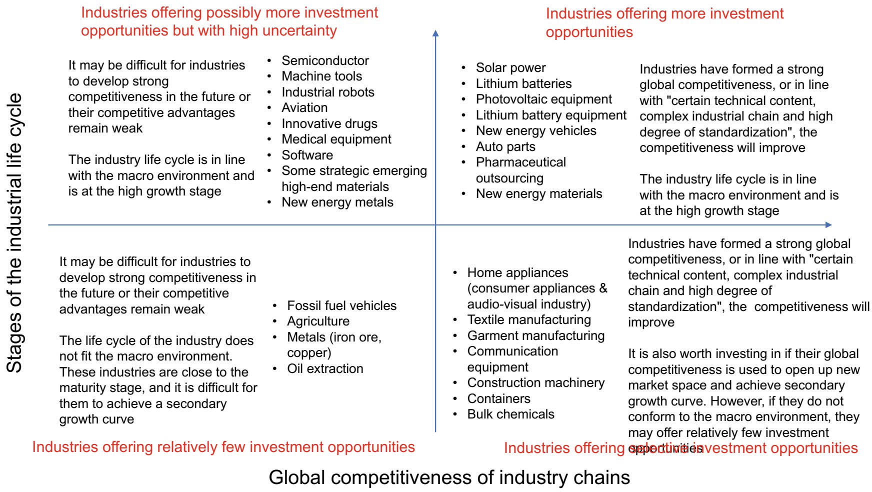

Fig. 18.7 Investment opportunities in China's industry chains based on the global competitiveness of industry chains and stages at the industrial life cycle. *Source* CICC Research

18.2.4.3 Pay Attention to Potential Risks from the Shift in Focus from Efficiency to Security and the Limits to Economies of Scale

The international situation is undergoing complex and profound changes, which will affect the evolution of the industry chain and capital market investment. Accounting for the technological gap theory[5], the relative differences in technological levels among countries will promote international division of labor and international trade. Leading countries offshore low value-added links to other countries or regions, thereby devoting more energy to high value-added links and innovation and R&D. The technology spillover effect also enables less technologically advanced economies to actively participate in the international division of work and achieve imitation, gradually narrow their gap with leading economies, and even catch up in the new technological upgrading cycle. This has also been the growth process of many Chinese manufacturing industries in the past. However, as international competition intensifies, the interregional relocation of industry chains may be interrupted, which is a risk factor that cannot be ignored. In addition, the development of some segments that could have been accelerated in cooperation will also be hindered, affecting the global competitiveness and growth cycle of industry chains.

Another potential concern for investment is that the benefits of economies of scale may come to an end; sustained technological innovation is the key. Past experiences have shown that developing China's single market of unprecedented size is of great importance to both China's own and global economic growth. However,

[5] Posner, Michael V. "International trade and technical change." *Oxford economic papers* 13.3 (1961): 323-341.

we think the benefits of economies of scale will gradually dry up in the process of scaling-up, and both China and the rest of the world face downward growth pressure. As US economist Edward F. Denison[6] pointed out, "economies of scale associated with expansion of the national market are presumably an influence tending toward a declining rate of economic growth"[7]. China's industrial upgrading is a process in which companies reduce costs, upgrade products, and enhance competitiveness through economies of scale. The benefits of scale are reflected in a growing number of products, ranging from footwear, toys, and furniture with relatively low added value to the mobile phone value chain, communication equipment, home appliances, and automobiles. Nevertheless, the benefits of such economies of scale will dry up one day. At that point, China's economic growth may have to rely more on technological advances.

Denison also said that "changes in technology and in business organization may constantly replenish opportunities for scale economies, and probably have done so, but there is no presumption that this is sufficient to offset the basic tendency"[8]. Indeed, when modern production methods have covered more and more people on the planet, especially after economies with a population as large as China have been modernized and scaled up, the pace of economic growth is decelerating and may have limits, as explained by the Club of Rome[9] in The Limits to Growth[10]. We believe that global economic growth will become increasingly dependent on, and approach the pace of technological progress. At that time, sustained technological innovation will become more critical to national and global economic growth.

[6] Beckerman, Wilfred. "The Sources of Economic Growth in the United States and the Alternatives Before Us." (1962): 935-938.

[7] Economies of scale associated with expansion of the national market are presumably an influence tending toward a declining rate of economic growth.

[8] Changes in technology and in business organization may constantly replenish opportunities for scale economies, and probably have done so, but there is no presumption that this is sufficient to offset the basic tendency.

[9] The Club of Rome is an international civil society on the study of futurology, founded by Italian scholar and industrialist Aurelio Peccei, Scottish scientist Alexander King.

[10] Meadows, Donella H., et al. "The limits to growth." *Green planet blues.* Routledge, 2018. 25-29.