Economic Studies in Inequality, Social Exclusion and Well-Being
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John Cockburn · Yazid Dissou
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Infrastructure and Economic Growth in Asia

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Infrastructure and Economic Growth in Asia

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ISBN 978-3-319-03136-1 ISBN 978-3-319-03137-8 (eBook)
DOI 10.1007/978-3-319-03137-8
Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013953311

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Summary

Public spending on infrastructure plays an important role in promoting economic growth and poverty alleviation. Empirical studies unequivocally show that underinvestment in infrastructure limits economic growth. At the same time, numerous other studies have shown that investment in infrastructure can be an effective tool in fighting poverty reduction. In that context, the financing of infrastructure has been a critical element of most economic growth and poverty reduction strategies in developing countries since the start of this millennium.

Several developing countries have recently started putting a policy emphasis on scaling up infrastructure investment. In this book, we provide a comparative analysis of the aggregate and sectoral implications of higher spending on infrastructure in three very different Asian countries: China, Pakistan, and the Philippines. In our analysis, we pay particular attention to the role of alternative financing mechanisms for increasing public infrastructure investment, namely distortionary and non-distortionary means of financing.

Using an intertemporal general equilibrium methodology that distinguishes between credit-constrained and unconstrained households, these studies tackle an important topic discussed in the literature on economic development: (i) how does infrastructure investment contribute to growth at the aggregate and sectoral level, and hence to poverty reduction; and (ii) what role do different financing methods of public spending on infrastructure play in facilitating economic development.

The comparative country analysis reveals that the effects of infrastructure investments on economic growth and poverty reduction can diverge significantly between countries and can also differ depending on the financing method used. However, a general conclusion emerges that public infrastructure investment generally increases growth and reduces poverty and inequality in the long run, although it can have negative impacts under certain circumstances and in some countries in

the short term. In addition, international borrowing is found to be better than tax financing in terms of job creation, improved productivity and complementarity with social protection measures.

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Introduction

John Cockburn, Yazid Dissou, Jean-Yves Duclos, and Luca Tiberti

Recent years have witnessed increasing interest in the relationship between economic development and poverty. An important reason for this has been the establishment of the Millennium Development Goals, which have set poverty reduction as a fundamental objective of development. The main factor explaining the salience of poverty reduction as a development goal is, in part, ethical. It is indeed widely considered ethically unacceptable that a large part of the world population still does not have the resources to achieve a basic level of living standards in an otherwise increasingly affluent world.

The most frequently advocated manner to achieve poverty reduction is through economic growth. Yet, growth is understood to be necessary but not sufficient to ensure a sustainable reduction in poverty. To do so, it must be inclusive in the sense that the poorest populations participate in and benefit from the growth process. Recent research has demonstrated that growth can vary tremendously in its power to reduce poverty, both across countries and over time. Its short-term and long-term poverty effectiveness depends on the structural changes that accompany the specific growth process. Even for those episodes in which growth does reduce short-term poverty, it is found in the literature that not all growth is equally inclusive of the poor. Hence, if one is interested in sustained poverty reduction and inclusiveness as an objective of development, then it is not enough to focus solely on growth.

Setting inclusiveness of growth as a development goal has three advantages. It reduces current poverty. It increases the impact of current growth on current poverty. It can finally increase future growth. Analyzing whether and how growth can be inclusive also enables a better understanding of long-term poverty. Long-term poverty is often linked to the difficulty for segments of the poor population to

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J. Cockburn et al. (eds.), *Infrastructure and Economic Growth in Asia*,
Economic Studies in Inequality, Social Exclusion and Well-Being,
DOI 10.1007/978-3-319-03137-8_1, © The Author(s) 2013

participate in the growth process, for example by finding better-paid employment in a growing sector. There is mounting suggestive evidence of the existence of poverty traps as higher return occupation or technology implies large sunk or fixed costs that are beyond the reach of the poor. Moving out of agriculture, where poverty rates are often much higher, is one example of such choices. Labor market participation, especially by women, who have, on average, lower possibilities to access loans, assets, new technologies, and lesser education, is another example. Any structural or policy induced trend that facilitates these transformations (i.e. shifts to higher value-added occupations and feminization of work) should foster pro-poor growth.

In this context, governments seek evidence and tools to assess the distributive impacts of alternative growth strategies. In this book, we develop and apply a new approach to simulate both the economy-wide impacts of such major investments and their household-level income and consumption impacts. More specifically, the approach combines a dynamic computable general equilibrium (CGE) model – which captures macro impacts as well as changes in prices, factor returns and employment – with a microsimulation analysis that maps these impacts to individual and household-level decisions and resulting incomes.

CGE models are widely recognized to be the best tool to conduct policy simulations of macroeconomic shocks and policies and to map out their impacts on specific sectors of production, factor markets, consumer prices, international trade and public finances. Indeed, governments in both developed and developing countries now routinely use CGE models to conduct simulations before enacting major policy reforms. Yet, the CGE literature is surprisingly poor in capturing growth – arguably the most important macro-economic shock or policy – including, for example, the dynamic impacts of trade liberalization through factor accumulation, technological diffusion, efficiency gains and increased foreign direct investment.

The macroeconomic literature has been far more productive in modeling growth, as these studies have been effective in capturing properly the transmission mechanisms between the economic environment and the accumulation of primary factors as well as productivity change. Yet these macro models are too aggregate to track down the more disaggregate sectoral and factor market impacts necessary to analyze the distributive consequences and, in particular, the participation of poorer populations in the growth process.

Most of the dynamic CGE models found in the inclusive growth literature are sequential in the sense that they are simply multi-period static models linked by a simple adjustment of the stocks of primary factors from one period to the other. In these models, saving and investment decisions, which are crucial in the growth process, are determined in an ad hoc manner like in static models, since households and firms do not for example take into account the future in their current-period decisions; they are myopic. This type of modeling strategy is unsatisfactory, as it does not make it possible to assess properly the impacts of government policies on factor accumulation as well as on their efficiency. Sequential CGE models cannot adequately capture the transmission mechanisms between changes in policy environment and investment decisions that are crucial for a good understanding of the

growth and distributive impacts of the proposed policy changes. There is a crucial need to develop a framework for policy analysis that can solve these deficiencies of recursive CGE models.

Intertemporal CGE models constitute a good candidate, as they provide a more realistic framework for modeling these crucial saving and investment decisions. Intertemporal CGE models assume that households and firms can behave rationally, for example by integrating their expectations of changes in current and future policy instruments or variables into current decisions. They can thus provide a coherent framework for analyzing changes in the economic environment that affect the accumulation of factors of production and their respective rates of return (wage rates for different categories of labor, returns to land, returns to capital...) over time.

The set of accumulable factors that intertemporal models can analyze is not limited to physical capital alone; these models can be used to analyze household decisions to invest in education (human capital) and hence government policies that affect, for example, the cost and returns to education. In the same vein, intertemporal models can be designed to capture the productivity effects of government spending on infrastructure.

Once the growth impacts are properly modeled and their impacts on key variables are correctly assessed, the poverty and inequality implications of proposed policy changes can be properly assessed using microsimulation techniques based on household survey data. We believe that this is an important methodological advancement since we are not aware of any model that examines the growth and distributive impacts of government policies in an intertemporal framework.

This approach is applied through the analysis of the distributive impacts of infrastructure investments in three large and divergent Asian countries: China, Pakistan and Philippines. Indeed, among possible growth strategies, investment in infrastructure is key. Infrastructure bottlenecks – in the quantity and quality of roads, railroads, ports, airports, communication facilities, etc. – constitute major constraints that increase the cost of purchasing inputs, bringing produce to markets, circulating information, networking among economic actors and that generally thus discourage investment and growth. Business surveys repeatedly cite infrastructure among the central criteria in national and international investment decisions.

Yet little is known about the distributive impacts of these investments and of the various mechanisms used to finance them. Indeed, governments can finance new infrastructure in a variety of ways – domestic or foreign loans, increases in a variety of taxes, cuts in other types of spending, etc. – that can be expected to have highly divergent impacts on poverty and inequality. The studies reported in this book develop and apply a rigorous framework to analyze the short- and long-term distributive impacts of infrastructure investment and of these different financing mechanisms in the case of three fast-growing Asian countries.

The book begins with a summary of the current state of the art in terms of theoretical and empirical analysis of infrastructure investments and their relationship to economic growth. This sets the background for the three case studies. The first of these sets out the methodological framework used in all three countries,

before applying it to the specific case of the Philippines. This is followed by applications to the cases of China and Pakistan. The book ends with a conclusion that compares and contrasts the key findings.

Beyond its contribution to the understanding of the growth and distributive impacts of infrastructure investments and their financing, the book constitutes a first step in providing tools to allow governments and other stakeholders to examine the role of other important growth strategies such as those that include investments in human capital (for instance, through education and health), research and development, agriculture, among many others.

Finally, this book is novel in another way. All three country studies were conducted by teams of researchers born and living in the countries they are analyzing. This gives them a unique and detailed understanding of the local economic and political context, which deepens their analysis and embeds their analysis and recommendations within local realities. Indeed, this book is the outcome of a program of research established by the Partnership for Economic Policy, a global network working to strengthen and promote a stronger voice for local researchers in national and international development policy debates.

PEP is financed by the Department for International Development (DFID) of the United Kingdom (or UK Aid) and the Government of Canada through the International Development Research Center (IDRC). This particular program of research received separate funding from the Australian Agency for International Development (AusAID). We thank participants in several PEP general meetings, the 2013 GTAP annual conference in Shanghai, the 2013 GDN annual conference in Manila, the 2012 international conference on CGE modeling – "Urbanization and Sustainable Development" – in Beijing and the 15th Sustainable Development Conference – "Sustainable Development in South Asia: Shaping the Future" – in Islamabad (2012) for helpful comments. We also salute the support and advice provided by governmental and non-governmental counterparts in all three study countries.

Infrastructure and Growth

Yazid Dissou and Selma Didic

Introduction

While a high rate of economic growth does not necessarily reduce inequality or poverty, there seems to be a consensus among researchers and policy makers that continuous, rapid economic growth is required for poverty alleviation. Governments around the world are continually looking for new strategies to increase the ability of their economies to produce goods and services. In this light, over the last two decades, economists have developed more sophisticated models to evaluate the potential economic impacts of different supply-side policies that aim to raise the productive capacity of the economy. Specifically, alongside modelling the main factors of production – physical capital and labour – these models seek to account for the concurrent use of non-traditional inputs, such as public infrastructure and education, as key contributing factors to economic growth.

The seminal papers of Romer (1986, 1990), Lucas (1988) and Barro (1990) have paved the way for the emergence of an entire class of endogenous growth models that seek to explicitly endogenize human capital accumulation and infrastructure as two of the main arguments of the aggregate production function. In this chapter, we provide a literature review on the modelling of infrastructure and education in growth models. At the theoretical level, we present and evaluate different strategies employed by endogenous growth economists to model human capital and infrastructure. At the empirical level, we discuss the empirical findings regarding the effects of infrastructure and education on growth and poverty alleviation, particularly in developing countries.

The remainder of this chapter is organized as follows. In the section "Infrastructure in Growth Models", we provide a rationale for the introduction of infrastructure into growth models. We then compare and contrast the different modelling

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J. Cockburn et al. (eds.), *Infrastructure and Economic Growth in Asia*, Economic Studies in Inequality, Social Exclusion and Well-Being,
DOI 10.1007/978-3-319-03137-8_2, © The Author(s) 2013

strategies applied in a subset of macroeconomic literature that focuses on explaining endogenous growth in terms of public infrastructure. We conclude that section of the literature review with an assessment of the available empirical evidence regarding the effect of infrastructure on both growth and poverty alleviation with a special focus on developing countries. We use the same structure in the section "Education in Growth Models" with regards to education, and the final section provides our concluding remarks.

Infrastructure in Growth Models

Theoretical Considerations

Overview

Before discussing the various approaches used to model infrastructure in growth models, it may be useful to provide the rationale behind using infrastructure as an argument of an economy-wide production function. Three studies carried out by Aschauer in 1989 emphasized, among other things, the difference between productive and unproductive public expenditures, and helped catalyze an empirical debate on the effects of government expenditures on productivity. An interesting summary of the empirical results of this literature appears in the World Development Report (World Bank 1994), and shows that infrastructure seems to have no effect on economic growth in some cases and appears to generate returns in excess of 100 % per year in other cases. These strongly contrasting findings may be explained, in part, by the extent to which researchers have successfully tackled various econometric challenges in estimating the relationship between infrastructure and growth. Both Estache and Fay (2009) and Gramlich (1994) pinpoint significant econometric problems arising in the macroeconomic time series models used to estimate aggregate production functions. These include: common trends in capital per capita and output per capita, omitted variable bias (e.g. energy prices), reverse causality, network effects, heterogeneity and poor data quality.

Reviewing the relevant studies in the literature on the infrastructure-growth nexus, and acknowledging that the connection between infrastructure and growth appears to vary across countries and over time as well as within countries and within sectors themselves, Estache and Fay (2009) suggest that increasing empirical agreement exists regarding the growth-enhancing effect of infrastructure. For instance, in a review of evidence produced by Romp and de Haan (2005, p. 6), 32 of 39 studies on OECD countries find a "positive effect of infrastructure on some combination of output, efficiency, productivity, private investment, and employment." Moreover, 9 of 12 studies on developing countries indicate a significant positive impact (Estache and Fay 2009, p. 15). In addition, by employing an econometric technique that accounts for biases arising from omitted variables and

that explicitly accounts for the government budget constraint, Bose et al. (2007) find that government capital expenditures as a share of GDP are positively and significantly related to per capita income growth across a panel of 30 developing countries over the 1970–1980 period. However, current expenditures are shown to have an insignificant effect on growth in these countries over this timeframe.

In this context, it is important to highlight the various transmission mechanisms through which infrastructure affects growth. The most conventional channel, first described in Aschauer (1989) and Barro (1990), is that public infrastructure investments enhance private sector productivity. Indeed, Aschauer (1989) attributed the 1970s U.S. productivity slowdown to the lack of infrastructural investment. This direct productivity effect of infrastructure investment captures the idea that an increase in public capital stocks (relative to private capital) has a positive but decreasing impact on the marginal product of all factor inputs (such as capital and labour). Hence, the cost of production inputs falls and the level of private production increases. As Agenor and Moreno-Dodson (2006, p. 9) point out, "this scale effect on output may lead, through the standard accelerator effect, to higher private investment – thereby raising production capacity over time and making the growth effect more persistent."

Agenor and Moreno-Dodson (2006) identify two additional conventional channels through which infrastructure may affect growth, namely complementarity and crowding out effects. The first channel promotes growth through private capital formation. That is, public infrastructure raises the marginal productivity of private inputs, thereby raising the perceived rate of return on private capital and possibly also increasing private sector demand for physical capital. The second channel, crowding out, captures the idea that, in the short run, an increase in public capital stocks may displace or crowd out private investment. This negative crowding out effect of infrastructure may turn into a long-term negative effect if the decrease in private capital formation persists over time.

In addition to the three 'conventional' channels above, recent studies have also identified a variety of other channels through which public infrastructure may impact growth. Estache and Fay (2009) suggest that, in addition to the channels mentioned above, investment in public infrastructure can also impact investment adjustment costs, the durability of private capital, and both the demand for and supply of health and education services. In the same vein, Agenor and Moreno-Dodson (2006) argue that infrastructure may reduce investment adjustment costs via two channels: through complementarity between public capital and private investment and through the decreased costs associated with capital reallocation between sectors following a shock.

Maintaining the quality of public infrastructure may positively affect growth by improving the durability of private capital. That is, increasing government infrastructure maintenance spending allows the private sector to spend less to maintain its own capital and thus to allocate its investment capacity to other uses, thereby generating an additional growth effect. Better infrastructure is also found to improve access to health care and education. By improving health and education outcomes, the impact of public infrastructure on growth is magnified or

compounded due to the interconnected relationship between education and health (Agenor and Moreno-Dodson 2006). Healthier individuals tend to study more, while more educated individuals also tend to be healthier.

Moreover, Agenor and Moreno-Dodson (2006) add labour productivity as another channel whereby public infrastructure indirectly increases growth. Better access to infrastructural facilities means that workers can get to their jobs more easily and perform their job-related tasks more rapidly. Other studies have also found evidence of various positive externalities induced by public infrastructure, including increased competitiveness, greater regional and international trade, expanded FDI, and finally higher profitability of domestic and foreign investment flows which raises investment ratios and boosts growth in per capita income (Fourie 2006; Fedderke et al. 2006; Richaud et al. 1999).

Hence, at the theoretical level, infrastructure could be modeled as having an effect on any given measure of output via two channels: directly as a production factor and indirectly by influencing total factor productivity (TFP). The general production function would take the following form:

$$Y = A(K_{PUB})f(K, L, K_{PUB}) \tag{1}$$

where Y is output, K is private capital, L is labour, A is TFP and K_{PUB} is public capital.

Still, modelling infrastructure in the context of endogenous growth has been based on a more restrictive production function, generally excluding the indirect impact of infrastructure via TFP. Such a modelling approach, motivated by Barro (1990), introduces government infrastructure expenditures as an argument of the production function, and is justified by reasoning that private inputs (K) are not a close substitute for public inputs. However, his assumption that public expenditures is a flow variable brought a wave of criticism, starting with Futagami et al. (1993) who modified Barro's original model (1990) by considering productive public expenditures as a stock variable, much like private physical capital is.

We can distinguish between two theoretical approaches to modelling the impact of infrastructure on growth. The first treats government infrastructure expenditures as a flow variable which directly enters the production function. The second treats public infrastructure as accumulated capital, rather than as current flows, and thereby represents infrastructure as a stock variable in the aggregate production function.

Modelling Infrastructure as a Flow Variable

Barro (1990) models infrastructure in the context of a simple AK endogenous growth model. The two building blocks of his model are a production function that incorporates public services (an expenditure flows variable) as an input to private production, and a Ramsey equation that captures the representative

consumer's optimization behaviour. For most of his analysis, he assumes a Cobb-Douglas production function:

$$y/k = \Phi\left(\frac{g}{k}\right) \tag{2}$$

$$y = A \cdot g^{\alpha} k^{1-\alpha}; \quad 0 < \alpha < 1 \tag{3}$$

where y is output per worker, k is capital per worker and g is the per capita quantity of government purchases of goods and services. α is the (aggregate) production elasticity of public services; the function also defines the share of public services in total output. Production is assumed to exhibit constant returns to scale with respect to the private stock of capital and the flow of public services provided by the government. Barro (1990) makes a theoretical assumption that the government is not engaged in production and does not own capital; rather, it buys a flow of output (e.g. services of highways, sewers, etc.) from the private sector. These services are paid for and made available to households and correspond to the input g. Moreover, Barro (1990) argues that it is the amount of government purchases per capita that matters since few government services are actually non-rival.

The second building block in the model is the consumption growth rate equation, derived from the utility-maximization problem of the infinite-lived household:

$$\frac{\dot{C}}{C} = \frac{1}{\sigma}(f' - \rho) \tag{4}$$

where f' is the marginal product of capital.

The income tax rate is set to finance the chosen level of expenditure:

$$g = T = \tau y = \tau k \Phi\left(\frac{g}{k}\right) \tag{5}$$

where T is government revenue and τ is the tax rate. By normalizing the number of households to unity, g represents aggregate expenditures and T aggregate revenues. This equation constrains the government to run a balanced budget.

Given the production function specified in Eq. 1, the marginal product of capital is:

$$f' = \Phi\left(\frac{g}{k}\right)\left(1 - \Phi' \frac{g}{y}\right) = \Phi\left(\frac{g}{k}\right)(1 - \eta), \tag{6}$$

where η is the elasticity of y with respect to g (for a given value of k), such that $0 < \eta < 1$. Since income is taxed to provide for public services, Eq. 4 is modified as follows:

$$\gamma = \frac{\dot{c}}{c} = \frac{1}{\sigma}\left[(1-\tau)\Phi\left(\frac{g}{k}\right)(1-\eta) - \rho\right] \tag{7}$$

Provided that the government sets g and T to grow at the same rate as y, g/k and η, then γ will be constant. As a consequence, in the steady state,[1] per capita consumption, per capita output and per capita capital will grow at the same rate, a positive function of the marginal product of capital.

By differentiating Eq. 7 with respect to g/y,

$$\frac{d\gamma}{d\left(\frac{g}{\gamma}\right)} = \frac{1}{\sigma}\Phi\left(\frac{g}{k}\right)(\Phi' - 1) \tag{8}$$

Barro (1990) shows that the decision to invest in public infrastructure has two opposing effects: a positive one, where an increase in productive government spending increases the marginal product of private capital and thus generates sustained per capita growth; and a negative one, where an increase in financing of public infrastructure by taxing income reduces per capita growth. The negative effect dominates when government size is large, while the positive effect dominates when government is small.

In Barro's (1990) model, to maximize growth, the government must set the tax rate equal to the elasticity of the public services g in aggregate production. In maximizing growth (Eq. 7) with respect to the tax rate τ, the government must set $\tau^* = \Phi = \alpha$. In the context of the model, this condition not only corresponds to maximum growth, but it also maximizes lifetime utility or welfare. In other words, to maximize the national growth rate and social welfare, the government sets the optimal level of the income tax financing public services as a share of national income to be equal to the contribution of public services to aggregate output in a competitive economy (i.e. the elasticity of the public services g in aggregate production). This result is crucially dependent on the Cobb-Douglas functional form used to represent technology.

This baseline approach to modelling infrastructure as a flow variable has been adopted and extended by several other authors. Some of these include Rivas (2003), Eicher and Turnovsky (2000), Yakita (2004), Ohdoi (2007), Chen and Lee (2007) and Park and Philippopoulos (2002). The main advantage of modelling infrastructure as a flow variable is that it produces highly tractable models (Fisher and Turnovsky 2013). Agenor (2007) observes that the flow specification generates results that are not qualitatively very different from studies employing the stock specification of infrastructure. However, it has been argued that as long as one is interested in modelling the impact of infrastructure on growth, the stock variable specification may be more appropriate or plausible. One of the reasons for this is that specifying infrastructure as a flow variable within the production function

[1] The economy is always in the steady state, i.e., there are no transitional dynamics.

implies that only newly established roads or buildings raise the level of private production, and that previously accumulated capital does not contribute to this increase.

As Fisher and Turnovsky (2013, p. 399) write, "the flow specification . . . is open to the criticism that insofar as productive government expenditures are intended to represent public infrastructure, such as roads and education, it is the accumulated stock, rather than the current flow, that is relevant."Furthermore, another criticism of the flow specification approach captures the idea that it may not be realistic to describe government expenditures on infrastructure as a non-rival good like aggregate knowledge. Public infrastructural expenditures may not always be complementary to private capital in the aggregate production function, and instead may be rival at the level of the aggregate economy through crowding out effects.

Modelling Infrastructure as a Stock Variable

Futagami et al. (1993) combine Barro's (1990) model with the assumption that government spending does not influence the aggregate production function directly, but only indirectly via the stock of public capital. By including two stock variables, Futagami et al. (1993) bring transitional dynamics into the model in contrast to the endogenous growth models employing the flow specification. The main finding of the Futagami et al. (1993) study is that Barro's (1990) result about optimal fiscal policy remains valid in the steady-state equilibrium even if government services are proportional to the stock of public capital (rather than capital expenditure flows), but not in the development transition phase. That is, when transitional dynamics are introduced into the model, the tax rate that maximizes welfare is found to be lower than the tax rate that maximizes growth under a log-liner utility function.

Futagami et al.'s (1993) modelling strategy of incorporating public infrastructure into an endogenous growth model differs from that of Barro (1990) in that government services are now accumulated like physical capital. In other words, the stock specification of infrastructure now requires the introduction of a government services accumulation equation:

$$\dot{g} = \tau y - \delta g \tag{9}$$

where $\delta \geq 0$ is the rate of depreciation, and g now stands for government services derived from public capital. The Cobb-Douglas production function exhibits constant returns to scale with diminishing returns with respect to each factor, the consumption growth equation is given by the Ramsey rule, and the flat-rate income tax that finances the chosen level of public expenditure remains as in the Barro (1990) model (i.e. Eqs. 2, 3, 4, and 5 of the Barro (1990) model). Integrating (9) backwards yields:

$$\dot{g} = \frac{\tau y}{g + \delta} \tag{10}$$

instead of Eq. 5 of the Barro model. Equation 10 of the Futagami et al. (1993) model now enters the production function (2) and the output growth rate Eq. 7. Because g grows at a constant rate in the steady state, the expansion factor $1/(g + \delta)$ does not change the underlying results of the utility maximization problem, such that the government, in maximizing growth, still chooses $\tau^* = \Phi$ (Tsoukis and Miller 2003). Hence, the steady-state growth-maximizing tax rate is equal to the production elasticity of government services, g, as in Barro (1990).

However, Futagami et al. (1993) find that maximizing the growth rate of the economy is not equivalent to maximizing social welfare. They argue that in an endogenous growth model with transitional dynamics and log-linear utility, "reducing the tax rate from the rate which attains the maximum national growth rate increases the agents' lifetime welfare" (Futagami et al. 1993, p. 622).

Subsequent studies, such as Fischer and Turnovsky (1998), Rioja (1999), Turnovsky (2004), Tamai (2007), Kalaitzidakis and Kalyvitis (2004), Tsoukis and Miller (2003) and Zhao and Kanamori (2007) have extended the basic Futagami et al. (1993) framework of modelling infrastructure as a stock variable. Following the tradition of Barro (1990) and Futagami et al. (1993), Tsoukis and Miller (2003) also seek to obtain the rule of optimal fiscal policy.

In contrast to previous studies that assumed that public services are derived from either flow expenditures or the stock of public capital, Tsoukis and Miller (2003) consider the case where public services are derived from both public capital stocks and expenditure flows. They also introduce private capital adjustment costs into their analysis. Tsoukis and Miller (2003) consider the following production function:

$$Y = K^{1-\varphi}\left(P^{\alpha}H^{1-\alpha}\right)^{\varphi}, \quad 0 < \varphi, \quad \alpha < 1 \tag{11}$$

where K and P are respectively the stocks of private and public capital and H is the flow of non-capital public expenditures. The term in brackets is a Cobb-Douglas production function of public services which generates constant returns to scale in the aggregate economy and provides a mechanism for endogenous growth. The government budget constraint is specified as follows:

$$\dot{P} = (\gamma - h)Y \tag{12}$$

where γ is now the tax rate. Total government expenditures is the sum of public investment (x)and non-capital public expenditure (h) as a share of output. Their study suggests that taxation has a negative effect on private returns to capital, while the effects of h and x are positive because spending on public investment and flow services enhances productivity. Tsoukis and Miller (2003) proceed to derive the optimal policies for growth. They find that the Barro rule, $\tau^* = \alpha$, used to maximize steady-state growth, also applies in a framework where public services are

derived from both public capital and flow services. However, according to Tsoukis and Miller (2003) and in line with the findings of Futagami et al. (1993), this rule is too high for welfare maximization.

As argued in Zhao and Kanamori (2007), most of the existing endogenous growth models which explicitly account for public infrastructure fail to consider the external effects of this infrastructure on consumption. In other words, the studies reviewed above, as well as many others, fail to account for the positive effect of public services on household utility. Zhao and Kanamori (2007) also observe that the flow specification of infrastructure is inappropriate since "what contributes directly to production and utility is the service flow of public infrastructure produced by capital." As a consequence, they include the stock of public infrastructure in both the household's objective utility function and the private production function.

On the production side, the authors allow the service flow provided by public infrastructure K_{gt} to be an argument of the production function:

$$y_{it} = A(k_{it})^{1-\alpha}\left(K_{gt}\right)^{\alpha} \tag{13}$$

Private capital is accumulated according to the following motion equation:

$$\dot{k} = (1-\tau)y_{it} - (\delta + n)k_{it} - c_t \tag{14}$$

On the consumption side, households gain utility from both consumption and spillover effects of service flows of public infrastructure:

$$U = U\left(c_t, K_{gt}\right) = Log\left(c_t, K_{gt}\right) \tag{15}$$

The government in the model is only assumed to provide public infrastructure, which is consumed by households as consumers and as producers without any direct payment. The production function of newly produced infrastructure (the infrastructure flow) is represented as:

$$I_{gt} = NL_{it}A_g[(1-\varphi)\tau y_{it}] \tag{16}$$

The infrastructure stock accumulation equation is given by

$$\dot{K}_{gt} = NL_{it}A_g[(1-\varphi)\tau y_{it}] - \delta_g K_{gt} \tag{17}$$

Maximizing lifetime utility of this infinitely lived household leads to the following consumption growth and private capital growth equations, which describe the transitional dynamics

$$\frac{\dot{c_t}}{c_t} = \left[(1-\alpha)(1-\tau)A\left(\frac{k_{it}}{K_{gt}}\right)^{-\alpha} - (\delta+\rho)\right] \tag{18}$$

$$\frac{\dot{k_{it}}}{k_{it}} = (1-\tau)A(k_{it})^{-\alpha}\left(K_{gt}\right)^{\alpha} - (\delta+n) - \frac{c_t}{k_{it}} \tag{19}$$

Clearly, the household consumption growth rate increases with public infrastructure. Since both capital and consumption grow at a constant rate in the steady state, we have:

$$k_{it}^{*} = [(1-\alpha)(1-\tau)A/(\delta+\rho)]^{\frac{1}{\alpha}}K_{gt} \tag{20}$$

$$c_t^{*} = \left[[(\delta+\rho)/(1-\alpha)] - \left(\delta+n\right)\right][(1-\alpha)(1-\tau)A/(\delta+\rho)]^{\frac{1}{\alpha}}K_{gt} \tag{21}$$

The steady-state per capita capital equation implies that consumption growth is positively related to infrastructure accumulation and is negatively related to the tax rate, the capital depreciation rate and the time preference rate.

In relation to the impact of infrastructure on investment, Zhao and Kanamori (2007) suggest that it would be possible for the individual household as a producer to produce up to the point where marginal product exceeds marginal cost if there is overinvestment in public infrastructure, which leads to an above normal profit for producers. The authors also state that the government should decide on the amount of infrastructure as well as the level of tax revenues required to finance the infrastructure provided.

So far, a common feature of the modelling strategies that employ the stock specification of infrastructure has been to assume a constant depreciation rate of public capital. Kalaitzidakis and Kalyvitis (2004) modify this assumption by introducing public capital maintenance expenditures. They begin with the following production function of representative firm i,

$$Y_i = K_i^{\alpha}(hL_i)^{1-\alpha}, 0 < \alpha < 1 \tag{22}$$

where K_i denotes the stock of private capital and L_i the labour used by firm i. Labour productivity, h, is a function of the existing aggregate stock of per worker private capital K, and per worker public capital K_g, such that:

$$h = \frac{K^{\beta}K_g^{1-\beta}}{L}, 0 < \beta < 1 \tag{23}$$

where L is the total labour force. With $\beta = 0$, one obtains the standard Barro (1990) endogenous growth model with productive public expenditures. The private capital accumulation equation is specified as:

$$\dot{K} = I - \delta_k K \tag{24}$$

where I denotes gross private investment. Furthermore, the transformation of output into private capital involves adjustment costs. The cost of investment faced by local firms is:

$$\Psi(I, K) = \left(1 + \frac{\varphi}{2}\frac{I}{K}\right) I \tag{25}$$

where $\varphi > 0$ is an adjustment cost parameter.

The novelty in Kalaitzidakis and Kalyvitis (2004) is that they allow the depreciation rate to vary with maintenance expenditures. They define public capital maintenance as "the deliberate utilization of all public resources which preserve the operative state of public capital goods" and specify the following public capital accumulation equation:

$$\dot{K}_g = G - \delta_g\left(\frac{M}{Y}\right) K_g, \text{ with } \delta_g'(.) < 0 \tag{26}$$

where δ_g is the public capital depreciation rate and G denotes public investment for 'new' public capital. The public capital depreciation rate is assumed to be a function of public capital maintenance expenditures as a share of aggregate output. It depends negatively on maintenance expenditures M and positively on usage measured by aggregate economic activity Y. The government budget constraint is then:

$$G + M = \tau Y \tag{27}$$

It is clear that this government finances its total expenditures ('new' public investment plus maintenance) through taxes imposed on total output produced by firms. Furthermore, the authors define the share of total government expenditures respectively going toward maintenance and 'new' investment as μ and $(1 - \mu)$:

$$M = \mu\tau Y \text{ and } G = (1 - \mu)\tau Y \tag{28}$$

The solution to representative firm i's infinite horizon profit maximization problem yields a system of two differential equations describing the dynamics of the economy:

$$\frac{\dot{z}}{z} = \delta_g(\mu\tau) + \left(\frac{q - 1}{\varphi}\right) - (1 - \mu)\tau z^{\omega} - \delta_k \tag{29}$$

$$\dot{q} = (r + \delta_k)q - (1 - \tau)\alpha z^{\omega - 1} - \left(\frac{(q-1)^2}{2\varphi}\right) \tag{30}$$

where $\omega = \alpha + \beta(1 - \alpha) < 1$, z denotes the private-to-public capital stock ratio, q is the shadow value of private capital stocks and r is the real interest rate. Since the dynamic system of the economy is nonlinear, the authors linearize these two dynamic equations near the steady state and then analyze how maintenance expenditures and taxes affect long-run growth.

The authors find that "the government can improve the growth rate of the economy by reducing (increasing) the share of maintenance expenditure in total expenditure if it is set at a high (low) level" as the tax rate is already set at the steady-state level. Concerning the changes in the tax rate, the authors consider two cases. In the first case, the economy has excess tax revenues, which reduces the marginal product of private capital and hinders private capital accumulation. A tax reduction in this case would stimulate private investment and growth until the economy reaches a new steady state described by a higher private-to-public capital ratio. In the second case, the economy has a shortfall of tax revenues, by definition, such that an increase in the tax rate would reduce private capital accumulation and increase public capital accumulation. The economy reaches a new steady state characterized by higher growth and a lower private-to-public capital ratio.

In contrast to Barro (1990), Futagami et al. (1993) and Tsoukis and Miller (2003), Kalaitzidakis and Kalyvitis (2004) find that the optimal tax rate to maximize long-run economic growth is larger than the production elasticity of public capital when maintenance expenditures are incorporated into the infrastructure-led endogenous growth model:

$$\tau^* = \frac{1 - \omega}{1 - \mu^* \omega} \tag{31}$$

They explain this finding as resulting from the beneficial impact that infrastructure maintenance spending has on public capital formation, which provides the economy with an additional benefit derived from the longer durability of public capital.

Regardless of whether the modelling strategy employs a stock or a flow variable approach to measuring infrastructure, there seems to be a common tendency within the theoretical literature to ignore the indirect impact of infrastructure via TFP. In other words, the common approach used to analyze the effects of public capital on output assumes that infrastructure only affects output directly as a production factor.

Empirical Models: Estimating the Effect of Infrastructure on Growth

Overview

In the next section, we review the empirical evidence regarding the effect of infrastructure on economic growth and its effect on poverty and income distributions in developing countries. As previously mentioned, there seems to be an increasing consensus around the idea that infrastructure, by raising labour productivity and lowering production and transaction costs, is beneficial for economic growth.

According to the findings of numerous studies, economic growth may just be the single most important determinant of poverty reduction (e.g. Lopez and Serven 2004; Dollar and Kraay 2002; Fanta and Upadhyay 2009). Through its positive contribution to economic growth, infrastructure investment presents a powerful tool that policy-makers can use to reduce poverty and raise living standards. At the same time, investments in transport, water, sanitation, irrigation, telecommunications and energy can directly improve the welfare of the poor simply by providing access to basic needs.

Ali and Pernia (2003) suggest that the benefits of infrastructure development for poverty reduction are manifested through two main channels: through the effect on income distribution (the direct channel), and through the effect on economic growth (the indirect channel). The 'income distribution effect of infrastructure' brings about improved employment and earnings prospects for the poor as a result of growth in the non-agricultural sectors of the economy and by increasing productivity in both the agricultural and non-agricultural sectors. By encouraging further economic activity, these productivity and employment gains drive the economic growth process leading to the so-called 'infrastructure growth effect'. Ali and Pernia (2003) provide a neat diagrammatical summary of the links running from infrastructure investments to real income and consumption of the poor, and consequently to poverty reduction (Fig. 1):

Indeed, the importance of the agricultural sector for growth, particularly in poorer developing countries, is widely recognized. Based on a sample of 40 developing countries, Thirtle et al. (2001) find the elasticity of poverty reduction with respect to agricultural productivity growth to be between 0.62 and 1.3, namely, the percentage of those living below the dollar a day poverty line falls by somewhere between 0.62 % and 1.3 % points for every percentage point increase in agricultural productivity. The findings of Bravo-Ortega and Lederman (2005), reported in the World Development Report (World Bank, 2007), indicate that, in developing countries, an increase in GDP brought about by an increase in agricultural labour productivity raises the incomes of the poorest quintile by an average of 2.9 times more than an equivalent increase in GDP arising from non-agricultural labour productivity.

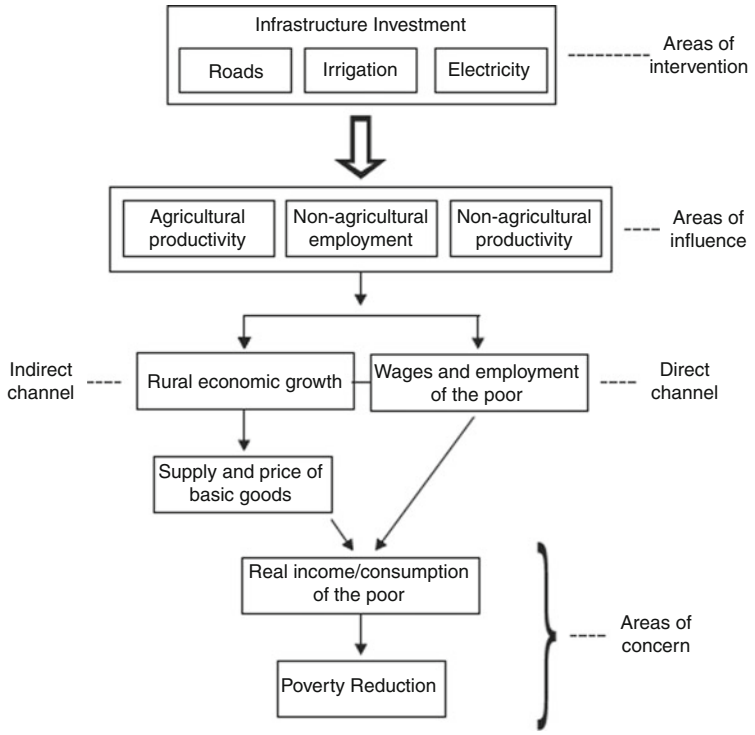

Fig. 1 Simple analytical framework depicting the links between infrastructure and poverty reduction (Source: Ali and Pernia (2003))

Hanmer and Naschold (2000) find that agricultural productivity growth has the greatest poverty-reducing effect in countries with the lowest levels of development, such as in Sub-Saharan Africa and South Asia. However, in more developed and urbanized regions of the world, such as East Asia and Latin America, growth originating in sectors other than agriculture seems to have larger poverty reduction effects (Hasan and Quibria 2004). In any case, the importance of agriculture for the poorest countries in the world is not solely related to its ability to reduce poverty, but also to its ability to drive broad-based economic growth reflecting agriculture's strong linkages with the rest of the economy.

Clearly, this evidence points to the observation that certain investments, particularly those aimed at developing and improving infrastructural facilities can positively impact agricultural and non-agricultural productivity growth. Such investments have the potential to help reduce poverty in developing economies through their spillover effects. Yet, little empirical attention has been paid to the channels through which infrastructure influences economic growth and poverty in developing countries. For the most part, econometric cross-country regression studies fall short of providing a detailed picture of the various linkages existing

between infrastructure development, economic growth, and poverty alleviation. However, these studies do provide useful insights into the magnitude and statistical significance of the effect of infrastructure on poverty and growth.

Next, we will take a look at some of these empirical studies which investigate the link between infrastructure, growth and poverty in developing countries. Most of these studies apply an individual, "physical" measure of infrastructure and thus attempt to gauge the economic and growth impacts of investments in a variety of infrastructure subsectors, particularly transport, energy and irrigation.

Empirical Studies on the Impacts of Road Infrastructure on Growth and Poverty

A substantial number of empirical studies find that investments in road (transportation) infrastructure contribute to both economic growth and poverty alleviation. These studies confirm that road infrastructure can have a direct and an indirect effect on reducing poverty in developing countries, although the extent of benefits derived can vary by income level. But while many studies suggest that road infrastructure development may be the single most important determinant of growth and poverty alleviation in developing countries, its presence does not appear to guarantee these outcomes. An increasing number of empirical studies in this area find that the effect of road infrastructure on economic growth and poverty alleviation is at least somewhat contingent on complementary investments, such as investments in human capital.

Kwon (2005) is one study that provides evidence on the direct and indirect contribution of road infrastructure to poverty alleviation. He finds that the positive impact of roads on poverty reduction in Indonesia resulted from broader economic growth and in particular improved wages and employment of the poor. The author uses 1976–1996 Indonesian provincial level panel data and splits samples to examine cross-sectional differences between provinces with good and bad access to transportation infrastructure via an instrumental variable approach (where good access is defined as above average road density[2] and bad access is defined as below average road density).

First, the author finds that road investments significantly increased GDP growth in provinces with both good and bad access to roads, with every 1 % of provincial GDP growth leading to a 0.33 % decline in poverty incidence in provinces with good roads and a 0.09 % decline in those with bad roads. Kwon (2005, p. 3) writes that this finding suggests that "the accumulation of road capital has a nonlinear contribution to poverty alleviation. As road capital is accumulated, the link between economic growth and poverty reduction becomes stronger and, in this way, roads produce a more efficient linkage between them."

[2] Road density is measured as the length of roads in kilometers per thousand square kilometers.

Second, the author finds that road infrastructure can contribute directly to reducing poverty, independent of its effect on GDP growth in each of two provinces. Compared with other types of government investments, such as those in education and health, Kwon's (2005) study reveals that the poverty rate is most sensitive to public investment in roads, such that a 1 % increase in road investment is associated with a 0.3 % drop in poverty incidence over 5 years. This is because provincial roads were found to directly improve the wages and employment of the poor in Indonesia. This finding leads the author to observe that road infrastructure has explanatory power on its own with regards to poverty incidence.

Fan et al. (2002) study is one of the rare econometric studies that attempts to trace the linkages and channels through which public investment in infrastructure operates to reduce poverty. They develop a simultaneous equations model to estimate the effects of different types of public infrastructure spending on agricultural growth and rural poverty in China using 1970–1997 provincial level data. The authors address the endogeneity problem by using a two-step procedure to estimate the full system of equations based on the maximum-likelihood technique. The first step involves estimating all equations other than the poverty equation, which is estimated in the second step using the predicted values of the independent variables of interest. Their results reveal that government spending on rural road infrastructure has a significant impact on poverty reduction not only through improved agricultural productivity, but also through increased non-agricultural employment opportunities and increased rural non-agricultural wages.

More specifically, the estimated elasticity of poverty with respect to agricultural labour productivity is found to equal −1.13. This elasticity equaled −0.56 with respect to non-farm income and −0.86 with respect to non-agricultural employment. Estimated (significant) elasticities with respect to road density in rural areas are 0.80 for agricultural labour productivity, 0.15 for rural non-agricultural wages and 0.10 for non-agricultural employment. In addition to road density, rural non-agricultural wages are also found to be affected by agricultural labour productivity: this elasticity is 0.87 and statistically significant.

Some studies have attempted to estimate the marginal returns to poverty reduction and sectoral GDP associated with public investment in roads. In contrast to Kwon (2005), Fan et al. (2002) find that road investment ranks third, after education and R&D investment, in terms of its poverty-reducing effect. Still, the poverty impact of road investment is found to be substantial: for every 10,000 yuan invested in rural road infrastructure, an average of 3.2 persons are brought out of poverty. With respect to the growth effect, road investment ranked second generating some 8.8 yuan of rural GDP for every yuan invested, slightly below the returns obtained for R&D investment. Among other types of investments, road investment appeared to produce the largest returns to rural non-farm GDP, at 6.7 yuan for each yuan invested.

Mu and van de Walle (2007) investigate the impact of a rural road rehabilitation project funded by the World Bank and implemented in Vietnam between 1997 and 2001. The objectives of the project were to develop local market activities and encourage economic development by targeting road improvements in poor

communities. The authors assess the short-term (1997–2001) and medium-term (1997–2003) impacts of the rural road rehabilitation project on a set of outcome variables closely related to local market development. In order to control for endogeneity arising from the communities' inclusion in the project, the authors apply a double difference estimator with propensity score matching under the assumption that time variant selection bias may affect the results.

A notable finding of the Mu and van de Walle (2007) study suggests that road improvements can exert an almost immediate impact on poverty reduction through the human capital channel. Specifically, among the 14 outcome variables considered in the study, the primary school completion rate was the only variable for which road improvements seemed to have a statistically significant impact in the short run. By 2001, the primary school completion rate rose by 15–25 % in communities included in the road rehabilitation project, and this impact appeared to only strengthen over time. The authors rationalize that roads encouraged students to complete their primary school education by providing them with access to secondary schools.

Significant impacts on other variables related to local market development emerged only in the medium-term. Mu and van de Walle (2007) find that communities that benefitted from the road rehabilitation project experienced larger increases in the availability of services and markets compared with those that did not. These changes further impacted the employment and livelihood patterns of households living in the beneficiary communities, such that the share of households relying on agriculture as the main source of income declined while the share relying on the services sector increased.

In fact, Mu and van de Walle (2007) demonstrate that the strongest development of markets was found in those communities which were characterized by an initially low level of market development. The magnitude of the impacts of road improvements on a host of market development variables considered in the study was generally larger for the poorest of the communities included in the project. This finding suggests that the extent of benefits derived from road infrastructure development can vary with income level.

Lokshin and Yemtsov (2005) develop this idea further. Using combined household and community level data and applying a propensity score matched difference-in-difference comparison between project beneficiaries and a control group, this study examines the average impact of a project that, among other goals, aimed to improve the road and bridge infrastructure in rural Georgia between 1998 and 2001.

Their results reveal that the road and bridge rehabilitation project generated significant economic benefits at the community level by increasing the number of small and medium-sized enterprises and by decreasing the importance of barter trade. However, the most notable finding of their study is that the road and bridge project benefited the poor and the non-poor differently. The non-poor benefited more in terms of improved access to emergency medical assistance and in greater opportunities for non-agricultural employment. The poor, however, benefited more in terms of increased female off-farm employment and increased sales of agricultural products.

The study by Khandker et al. (2009) corroborates the findings of Mu and van de Walle (2007) that rural roads can contribute to poverty alleviation by providing access to markets and human capital facilities. However, in contrast to Mu and van de Walle (2007), Khandker et al. (2009) further extend the idea that the poverty effects of road investments can differ by household type.

The authors first assess the impacts of two road projects in Bangladesh (RDP and RRMIMP)[3] on a range of household outcomes[4] using householdlevel panel data. They apply a fixed effect estimation approach to control for heterogeneity among households and among communities. The results reveal that rural road infrastructure can promote poverty reduction through higher prices of agricultural products (which increased by 4–5 %), lower input prices and transportation costs (fertilizer prices fell 5 % and transportation costs decreased by 36–38 %), higher men's agricultural wages (which increased 27 % in RDP villages only) and increased agricultural production (which rose by 30–38 %). The authors further observe that road development, by supporting an increase in demand for labour, can generate benefits for households beyond those outlined earlier. Higher agricultural wages, brought about by an increase in demand for labour, increased household labour supply in RDP villages(male monthly employment hours rose by 49 % and female monthly employment hours rose by 51 %). However, no similar statistically significant results for household labour supply were found for RRMIMP villages.

In addition, Khandker et al. (2009) find that road development led to a statistically significant increase in annual per capita consumption of 11 % in both project villages and to an increase in the school participation rate for boys (which climbed by 14–20 %). While the schooling of girls also increased significantly in RRMIMP villages (14 %), this estimate, although positive, was barely significant in RDP villages.

Looking at the distribution of benefits resulting from improved road infrastructure, Khandker et al. (2009) find that gains in consumption accrue disproportionately to the very poor, but only in RRMIMP villages. For the RRMIMP sample, the consumption benefits of road investment primarily accrue to the poorest households, i.e. those below the 15th percentile of the overall distribution. For the RDP sample, consumption benefits are significant and positive in all quintiles and average about 12–16 % in each quintile.

Finally, the authors estimate the poverty reduction effect of road infrastructure projects and find it to be significant. Their findings suggest that road infrastructure projects have the potential to reduce poverty by 5–7 %.

[3] Rural Development Project (RDP) and Rural Roads and Markets Improvement and Maintenance Project –II (RRMIMP). The first phase of the RRMIMP survey (RDP) collected benchmark information on 872 households from 18 villages during May–September 1997, and the second phase (RRMIMP) covered the same households over August 2000–February 2001.

[4] The outcomes of interest include variables such as household transport expenses, fertilizer prices, male agricultural wages, agricultural output, male and female labour supply, and boys' and girls' schooling (5–17 years: HH average).

Fan and Zhang (2008) is another study which provides evidence on the importance of the market access channel in alleviating poverty in poor countries. The study builds on the conceptual framework and modelling approach developed previously in Fan et al. (2002). Using a full information maximum likelihood technique applied to a simultaneous equations model, the authors examine the various channels through which government expenditures on rural roads affect rural poverty and agricultural production in Uganda.

Similar to the findings of the Fan et al. (2002) study conducted for the case of China, the results reveal that agricultural labour productivity and non-farm employment are significant factors determining the extent of rural poverty in Uganda. Fan and Zhang's (2008) estimates suggest that a 1 % increase in agricultural production or non-farm employment would lift about 0.27 % of the rural poor out of poverty. However, higher rural wages were found to have no statistically significant effect on rural poverty, which the authors argue may be due to the presence of surplus rural labour in Uganda.

Fan and Zhang (2008) examine the poverty impacts of road infrastructure by analyzing the marginal returns to public investment of different types of roads. Their calculations indicate that, among the different types of roads, feeder (dirt) roads have the largest impact on poverty reduction across Uganda, such that an additional million shillings invested in building feeder roads would allow 33 persons to escape poverty in Uganda. For murram (gravel) and tarmac (tarred) roads, the authors estimate that nine persons would be able to rise above the poverty line for each additional million shillings spent on these roads.

Fan et al. (2002) carry out a similar study using Tanzanian household level data. Their calculations of marginal returns to public investment in road infrastructure indicate that for every shilling invested, household income rises by 9.13 shillings. The authors also estimate that for every one million shillings invested in roads, on average, 27 persons are lifted out of poverty. Road investments are also found to have the largest poverty impacts in the Central and Western regions of Tanzania and in the South Highlands, where each million shillings spent on roads leads to 60–75 persons exiting poverty.

An increasing number of empirical studies seem to support the idea that strong complementarities exist between investments in road infrastructure and investments in other sectors of the economy, particularly in education. Jalilian and Weiss' (2004, p. 3) research provides evidence of a positive relationship between infrastructure and economic growth, with the caveat that this relationship is only significant in the presence of human capital development.

Jalilian and Weiss (2004) derive this finding based on their study on the impact of road infrastructure[5] on economic growth and poverty across a sample of developed and developing countries. The authors apply a range of estimation techniques to find that the road infrastructure variable on its own is insignificant in all estimations. Rather, the findings reveal the existence of complementarity between

[5] As proxied by length of road per capita.

road infrastructure and human capital,[6] as captured through an interactive term. In all reported regressions, this interactive term is found to be negative and highly statistically significant.

The authors' preferred panel instrumental variable fixed effect (PIVFE) technique yields an elasticity of poverty with respect to infrastructure or human capital of −0.35, when poverty is defined as $1 US per day. This elasticity is −0.53 for the $2 US per day poverty line.

Furthermore, the authors find that the poverty elasticity with respect to infrastructure (human capital) varies directly with human capital (infrastructure). Specifically, Jalilian and Weiss (2004) show that, in the case of a $1 US a day poverty line, a 25 % increase in secondary school enrollment rates raises the poverty elasticity with respect to road infrastructure from −0.35 to −0.38. An increase in secondary school enrollment of 50 % and 75 % raises this elasticity further to −0.40 and −0.45, respectively. In the case of the $2 US a day poverty line, the elasticity is even larger, and ranges from −0.60 for a 25 % increase in secondary school enrollment to −0.74 (for a 75 % increase).

Balisacan and Pernia (2002) also show the importance of complementarity between public investments in infrastructure and human capital. In fact, using provincial level data for the Philippines from the 1980s and 1990s, their estimates show that road infrastructure, as measured by concrete-equivalent roads per square kilometer, can in fact significantly reduce the welfare of the poor, unless complemented by investments in human capital. As stated by Balisacan and Pernia (2002, p. 16), providing access to markets and information alone may "exert an adverse impact on the poor through such channels as factor-market and political-economy processes." Only when road infrastructure is coupled with human capital (measured as the mean years of schooling of household heads), do the authors find that the welfare of the poorest improves, such that a 1 % improvement in roads and schooling results in a 0.11 % increase in the mean consumption expenditures of the bottom 20 % percent of the population.

Empirical Studies on the Impacts of Irrigation Infrastructure on Growth and Poverty

According to the empirical literature, irrigation infrastructure can also contribute positively to reducing poverty in developing countries, both directly and indirectly. Hussain and Hanjra (2004, p. 12) provide a comparative review of recent research on the relationship between irrigation infrastructure and poverty and find that "irrigation is a positive determinant of income, a negative determinant of poverty and households having access to irrigation (and complementary inputs) are less likely to be poor."

[6] As proxied by secondary school enrollment.

Furthermore, their review of the quantitative evidence finds that the incidence of poverty is 20–30 % lower in irrigated regions of Asia than in rainfed regions. This is because, as Hussain and Hanjra (2004) observe, irrigated areas tend to have higher cropping intensity and crop productivity, and are thus more likely to exhibit higher labour productivity, employment and household incomes than rainfed areas.

In the case of China, Fan et al. (2002) find that irrigation infrastructure directly contributes to the growth of the agricultural sector, and hence, to poverty alleviation. Specifically, Fan et al. (2002) find that the elasticity of agricultural GDP with respect to irrigation infrastructure (both in per capita terms) equals 0.41 and is statistically significant.

Based on the estimated returns to public investment in irrigation, their findings demonstrate that road infrastructure exerts a stronger poverty-reducing effect than irrigation infrastructure. Namely, for every 10,000 additional yuan invested in irrigation infrastructure, 1.33 poor persons are lifted above the poverty line compared with 3.22 for road investment. This, as the authors explain, may be due to the observation that "irrigation affects poverty reduction solely through improved agricultural productivity" Fan et al. (2002, p. 45).

Balisacan and Pernia (2002) illustrate that irrigation infrastructure directly improves the welfare of the poor in Indonesia. Their estimates show that a 1 % increase in the proportion of irrigated farm area to total farm area leads to a 0.23–0.31 % increase in the mean per capita consumption expenditures of the bottom 20 % of the population. Interestingly, Balisacan and Pernia (2002) find that the irrigation infrastructure variable is positive and statistically significant on its own (i.e. without being complemented by other investments, such as in human capital) in contrast to their findings regarding road infrastructure. This finding suggests that investments aimed at improving the quality of land may be more effective in reducing poverty in land-scarce, labour-abundant developing countries.

Huang et al. (2005) conduct a comprehensive study on the impact of irrigation infrastructure on rural incomes, poverty and the income distribution. They use data from a randomly selected, almost nationally representative sample of 60 rural villages in six Chinese provinces.

The study confirms previous studies' findings that irrigation has a strong role to play in poverty alleviation. Namely, Huang et al. (2005) find that the incidence of poverty would fall by 1.6 % points if all non-irrigated agricultural land were irrigated. This translates into 12 million fewer persons living in poverty. In addition, Huang et al. (2005) show that irrigation infrastructure (measured as irrigated land per capita) increases annual per capita household income through its positive effect on cropping income. In fact, cropping income derived from irrigated land is found to have the largest marginal effect on reducing income inequality in rural China, such that a 1 % increase in total cropping income from irrigated land would decrease the Gini income coefficient by 0.1 %.

Bhattarai and Narayanamoorthy (2003) provide additional evidence of the positive impact of irrigation on poverty alleviation. Their study shows that among all the variables included in the analysis, irrigation infrastructure had the strongest

influence in reducing poverty in India over 1970–1994 (an elasticity of −0.37), and this impact was twice as large as that of rural poverty.

As in the case of road infrastructure, empirical evidence demonstrates the importance of complementarity between public investments in irrigation infrastructure and human capital. For example, van de Walle's (2000) study of irrigation infrastructure in Vietnam finds that strong complementarities exist between returns to irrigation infrastructure and human capital, as measured by adult attainment of primary education. His estimates suggest that increasing the primary schooling of all household heads by five full years (and that of other adults by one standard deviation) would lead to crop incomes being 36 % higher on irrigated farms than on non-irrigated farms. His simulation results also show that the benefits of higher human capital would largely accrue to the poorest persons living in irrigated areas.

Empirical Studies on the Impacts of Electricity on Growth and Poverty

Empirical studies on the impact of electricity infrastructure on growth and poverty alleviation is relatively limited, compared to the abundance of literature studying road or irrigation infrastructure. The existing studies, however, provide mixed findings on the impact of electricity infrastructure on poverty.

Fan et al. (2002) find that electricity infrastructure exerts no statistically significant effect on either agricultural labour productivity or non-agricultural labour productivity in China. It also has an insignificant impact on rural non-farm wages. However, electricity infrastructure is found to contribute significantly to non-farm employment growth, and ranks better in its poverty impact than investments in irrigation infrastructure. Specifically, for every additional 10,000 yuan spent on electricity infrastructure, 2.3 people are brought above the poverty line, compared to 1.3 persons for the case irrigation infrastructure. As the authors explain, these results may be explained by the fact that access to electricity is important for the expansion of the non-agricultural sector.

On the other hand, Balisacan and Pernia (2002) show that access to technology (as proxied by the proportion of households with access to electricity) has no statistically significant impact on the welfare of the poor in the Philippines. What is more, access to electricity coupled with human capital is still found to yield an insignificant result in all regressions. However, an analysis of the differential impact of electricity infrastructure shows that richer households tend to benefit more from access to electricity than the poor. Namely, a 1 % increase in the proportion of households with access to electricity improves the welfare of the third and the fourth quintile by 16.2 % and 14.4 %, respectively. In contrast, the first and the second quintiles see a 4.9 % and 9.8 % improvement in their welfare, respectively.

In contrast, based on Ugandan data, Deininger and Okidi (2002) find that access to key public goods, such as electricity, critically determine households' ability to increase its income and to reduce the risk of falling into poverty. Their results show that households with access to electricity had higher incomes (3.5 percentage

points) and expenditures (6 percentage points) than those who had no such access. In addition, multinomial log it regressions show that households with electricity access had a 20 % higher chance of not falling into poverty than those that did not. As Deininger and Okidi (2002) explain, this effect most likely emerges due to the indirect effects of electricity availability (e.g. higher demand for labour) which reduce households' vulnerability to poverty.

Empirical Studies Using an Aggregate Index of the Infrastructure Stock

While the empirical literature reviewed earlier tended to use various proxies for infrastructure, several studies have attempted to quantify the overall effect of infrastructure on growth and poverty by constructing an aggregate index of the infrastructure stock. Some examples of these studies are Calderon and Serven (2004), Calderón and Chong (2004) and Sahoo and Dash (2009).

Calderon and Serven (2004) construct an aggregate index of the quantity of infrastructure using three independent, physical measures of infrastructure: the number of main telephone lines per 1,000 workers, the electricity generation capacity of the economy in MW per 1,000 workers and the length of the road network (km roads/km^2 of land area). The authors also construct an aggregate index of infrastructure quality using information on the waiting time for telephone main lines in years, the percentage of transmission and distribution losses in the production of electricity and paved roads as a share of total roads.

Using panel data from 1960 to 2000 for a large sample of developed and developing countries, Calderon and Serven (2004) find that the quantity of infrastructure has a robust positive effect on growth, all else equal, and a one standard deviation increase in the stock of infrastructure raises the economic growth rate by 3 percentage points. The quality of infrastructure is also found to have a positive, albeit less empirically robust, growth effect. In this case, a one standard deviation increase in the quality of infrastructure raises the economic growth rate by 0.68 percentage points, but this effect is only significant in their preferred GMM-IV estimation technique.

Furthermore, Calderon and Serven (2004) find that both the quantity and quality of infrastructure have a robust negative effect on income inequality. Here, one standard deviation increase in the infrastructure quantity index reduces the Gini coefficient by 0.06, while an analogous increase in the infrastructure quality index reduces the Gini coefficient by 0.01. These results lead the authors to conclude that "infrastructure development may be a key win–win ingredient for poverty reduction" (Calderon and Serven 2004, p. 26).

Calderón and Chong (2004) provide further evidence that the quantity and quality of infrastructure are both negatively related to income inequality. Using physical measures of roads, railways, telecommunications and energy, they also construct indices for both the quantity and quality of infrastructure. They apply the GMM-IV difference estimator to panel data spanning from 1965 to 1995 for sample of developed and developing countries. Their results show that the quantity of

infrastructure has a larger impact on reducing income inequality in developing countries than in developed countries, while the inequality-reducing effect of infrastructure quality is larger for developed countries.

Sahoo and Dash (2009) develop an index of infrastructure quantity to estimate its impact on economic growth in India over 1970–2006. Their infrastructure index incorporates six measures: per capita electricity power consumption, per capita energy use, telephone lines (both fixed and mobile) per 1,000 people, rail density per 1,000 people, air transport, freight in megatons per kilometer and paved roads as a share of total roads.

The authors estimate three production functions which all include the infrastructure stocks index as an input factor alongside varying private inputs. The results show that the long-run output elasticity of infrastructure is positive and statistically significant in all cases, and ranges from 0.24 to 0.35. Interestingly, their results reveal that the output elasticity of the infrastructure index is higher than that of private capital and total real investment, implying that infrastructure has contributed more strongly to economic growth in India than either of these two variables.

Education in Growth Models

The importance of human capital in facilitating economic growth and in raising living standards is widely recognized in policy and academic circles. Education is a primary source of human capital. In fact, as Aghion and Howitt (1998, p. 355) write, "education requires human capital as an input as well as producing it as an output." At the same time, ideas and inventions, which arise from human capital accumulation, are directly related to the pace of economic growth. Education thus provides an important foundation for both public and private strategies to develop human capital.

At the theoretical level, there exists strong support for education as a key factor driving economic growth. Endogenous growth models as pioneered by the works of Nelson and Phelps (1966) and Lucas (1988) provide valuable insights into the mechanisms through which education promotes economic growth and development. On the one hand, education increases the skills and capacity of workers as a production factor, and on the other hand, confers a series of positive externalities that start a "ripple effect" throughout the economy.

Theoretical Considerations

As Aghion and Howitt (1998) observe, there are two common approaches to modelling education within theoretical endogenous growth models: Lucas and Nelson-Phelps-type modelling. The first modelling approach presents an extension of the neoclassical Solow model, with the concept of capital broadened to include

human capital accumulation. Within this approach, *accumulated* human capital enters into the production of goods and services as a *factor input* and is the primary source of sustained economic growth.

In contrast, the second modelling approach is explicitly concerned with the indirect contribution of human capital to output. In these theoretical models, the *level* of human capital stocks can stimulate economic growth via technological change. In particular, a higher level of human capital at a given point in time (rather than a given rate of change as in Lucas) can increase growth either though new innovation (e.g. Romer 1990) or old innovation (Nelson and Phelps 1966).

Lucas-Type Modelling of Education

Lucas (1988) builds an endogenous growth model that includes human capital accumulation as an additional factor input in the aggregate production function of an economy. He specifies Cobb-Douglas technology with constant scale returns to individual human capital h and private capital k (with shares given by $1 - \alpha$ and α, respectively). The technology also includes a term for economy-wide average human capital, H:

$$y = Ak^{\alpha}(uh)^{1-\alpha}H^{\gamma} \tag{32}$$

The economy considered by Lucas (1998) is composed of infinitely-lived individuals who, at any given point in time, decide to use a fraction u of their time to work and a fraction $(1 - u)$ to acquire education, which is the primary method to accumulate human capital. The law of motion for human capital is:

$$\dot{h} = \delta h(1 - u) \tag{33}$$

where $\delta > 0$ is a parameter which denotes human capital productivity. Since human capital accumulation is specified as a linear function of the level of human capital, human capital is an engine of growth in the Lucas (1988) model. In the steady state, output and human capital grow at the same rate, and depend on δ and the equilibrium value of u. This can be observed from the solution to the representative consumer's intertemporal utility maximization problem:

$$g = \delta(1 - u^{*}) \tag{34}$$

As noted by Aghion and Howitt (1998), time spent on education can be shown to depend negatively on the time preference rate ρ and the coefficient of relative risk aversion σ, and positively on the productivity of schooling δ, such that:

$$g = [(1 - \beta + \gamma)(\delta - \rho)]/[\sigma(1 - \beta + \gamma) - \gamma] \tag{35}$$

$$1 - u^* = [(1-\beta)(\delta-\rho)]/\delta[\sigma(1-\beta+\gamma)-\gamma] \tag{36}$$

This model provides the basis for Lucas' (1988) main argument that economic growth is sustainable in the long run if growth in human capital continues without limit. Sustained growth is achievable in the Lucas (1998) model due to the assumption of constant returns to accumulated human and private capital, irrespective of the numerous externalities generated by human capital. Specifically, the model generates positive growth even in the absence of externalities ($\gamma = 0$), since long-run growth depends on private and human capital investments which (presumably) generate constant returns to human and private capital accumulation. In the presence of positive externalities ($\gamma > 0$), there are increasing returns to all factors of production. This possibility, as discussed in Aghion and Howitt (1998), suggests that individuals and firms would tend to underinvest in education if it were left to the free market.

In contrast to Lucas (1988), Tamura (1991) excludes the human capital externality parameter from the aggregate production function, and instead introduces it into the human capital accumulation equation:

$$y = Ak^{\alpha}(uh)^{1-\alpha} \tag{37}$$

$$\dot{h} = \delta[h(1-u)]^{\beta}H^{1-\beta} \tag{38}$$

Thus, economy-wide average human capital H represents an input into the production of individual human capital h. This allows Tamura's (1991) model to correspond better with the idea that individuals learn from the knowledge of others. The economy can sustain long-run growth only if β is less than 1.

Furthermore, Tamura's (1991) model suggests that individuals with below-average human capital gain the most from education by the externality effect, relative to individuals with above-average human capital. Tamura (1991) writes that individuals with low levels of human capital can acquire existing knowledge, while individuals with the highest level of human capital are most likely already at the 'frontier of knowledge'. Thus, the human capital of individuals with below-average human capital grows faster than that of individuals with above-average human capital, such that "an initially heterogeneous population converges to a homogenous population" (Tamura 1991, p. 524). If such a knowledge spillover effect exists across regions, or even countries, then Tamura's (1991) model implies that convergence in terms of both the growth rates of income and the level of per capita income can be achieved without mobility of any of the production factor inputs.

In contrast to Lucas (1988) and Tamura (1991), Rebelo's (1991) model does not give rise to knowledge externalities. In Rebelo's (1991) model, production is characterized by Cobb-Douglas technology and combines a fraction (φ) of the private capital stock with NH efficiency units of labour, which arises from N hours of work combined with H units of human capital:

$$Y = A_1(\varphi K)^{1-\gamma}(NH)^{\gamma} \tag{39}$$

Furthermore, in contrast to Lucas (1988), Rebelo (1991) introduces private capital into the human capital accumulation equation, while retaining the assumption of constant returns to the accumulation of human and private capital stocks. Each worker has one unit of time in each period and consumes L hours of leisure, which are exogenously specified. The remaining $1 - L - N$ hours are devoted to accumulating human capital and generate $(1 - L - N)H$ efficiency units of labour. Human capital depreciates at rate δ and is produced according to the following equation:

$$\dot{H} = A_2[K(1-\varphi)]^{1-\beta}[(1-L-N)H]^{\beta} - \delta H \tag{40}$$

An interesting property that arises from Rebelo's (1991, p. 510) model is that the steady-state growth rate of the economy increases in the total number of hours worked and in the total number of hours devoted to human capital accumulation, implying that the "economies with hard-working agents will grow faster".

In further contrast to Lucas (1988), Rebelo (1991) shows that the income tax rate can affect the steady-state growth rate when private capital is introduced as an input into the human capital accumulation equation. In this case, higher income taxes lower the long-run growth rate of the economy.

Both Lucas (1988) and Rebelo (1991) assume that an individual's return to education remains constant regard less of the initial level of human capital. However, the return may not be constant over an individual's lifetime as suggested in Becker (1964). Azariadis and Drazen (1990) reformulate the Lucas (1988) model within an OLG framework to deal with the issue of variable returns over an individual's life time. The authors assume that there exists an intergenerational externality to education, such that the present generation of individuals inherit the aggregate human capital accumulated by the previous generation of individuals. Following Aghion and Howitt's (1998) exposition of Azariadis and Drazen's (1990) model, the human capital accumulation equation is specified as:

$$h_{2,t} = \left(1 + \gamma(\upsilon_{t-1})\upsilon^{\theta}\right)h_{1,t} \tag{41}$$

where $h_{2,t}$ is the accumulated human capital of an old individual born at date t, and $h_{1,t}$ is the accumulated human capital of a young individual born at date t, $h_{1,t} = h_{2,t-1}$. The fraction of time allocated to education by a young individual born at date t is denoted as υ and υ_{t-1} is the amount of time devoted to education by the previous generation.

The central idea put forth by Azariadis and Drazen (1990) is that the positive externalities generated by human capital may give rise to the possibility of two locally stable balanced growth paths. One path is described as an "underdevelopment trap" and is characterized by low labour quality and zero growth in per capita income. An economy could fall into an underdevelopment trap if previous

generations did not invest sufficiently in education, thereby curtailing the acquisition of skills by future generations and their investment in education. However, if the education investment of the previous generation was sufficiently high, individuals in subsequent generations will also invest more in education and thereby contribute to future growth. This is the high-growth path which exhibits higher labour quality and positive growth.

The intuition behind this result is that economies that find themselves in an "underdevelopment trap" have very low initial stocks of human capital, such that the marginal return to investments in education is less than the opportunity cost of withdrawing resources from goods production. Consequently, growth in the stock of human capital remains stagnant as does growth in per capita incomes. In contrast, economies on a high-growth path are characterized by a larger initial stock of human capital, such that the returns to investments in education are sufficiently high to continue spending on education. As a result, the economy follows a balanced growth path with a constant human-to-physical capital ratio and exponential per capita income growth.

Despite a strong theoretical case for a causal link running from education to economic growth, recent theoretical studies have strived to explain why higher public investment in education may not necessarily always lead to higher growth. These studies suggest that the positive effect of higher public investment in education can be diminished or even negated via general equilibrium effects when other economic factors which impact human capital accumulation are considered.

A theoretical study carried out by Teles and Andrade (2008) looks into the impacts of government investment in basic education on both individual investments in higher education and economic growth within an overlapping-generations framework. Their study aims to explain why some countries with high levels of public investment in basic education grow slowly. They find that countries with high public spending on basic education with little or no investment in higher education may grow slowly as income taxation can distort an individual's incentive to invest in higher education.

They arrive at this result by first constructing a model that includes no government involvement in education and then compare its results to those derived from a model that includes the government. Teles and Andrade (2008) consider individuals which live for three periods, and who consume in the second and third periods, respectively according to the following equations:

$$c_t = (1 - h_t)H_t \tag{42}$$

$$c_{t+1} = H_{t+1} \tag{43}$$

where c is the individual's consumption, h is the number of hours dedicated to human capital accumulation and H is the individual's initial stock of human capital. The individual's human capital stock in period $t + 1$ is given by:

$$H_{t+1} = h_t + H_t \tag{44}$$

In this model, the production function is given by multiplying the number of hours worked by the individual's human capital stock. In the first period, the individual chooses the number of hours to allocate to work and to human capital accumulation in order to maximize an intertemporal utility function. The individual's maximization problem is:

$$Max_h \left(\frac{[(1-h)H]^{1-\theta} - 1}{1-\theta} \right) + \beta \left(\frac{(h+H)^{1-\theta} - 1}{1-\theta} \right) \tag{45}$$

where $H \equiv H_t$ and $h \equiv h_t$. The individual's optimal choice of h is given by:

$$h = \frac{\beta^{(1/\theta)} H^{(\theta-1)/\theta} - H}{1 + \beta^{(1/\theta)} H^{(\theta-1)/\theta}} \tag{46}$$

This result shows that for low risk aversion($\theta < 1$), the amount of hours that individuals devote to accumulating human capital is positively related to his or her initial human capital stock. Teles and Andrade (2008, p. 356) emphasize the importance of this result: "the more human capital an individual accumulates during childhood, the more time this individual will allocate towards accumulating human capital in adulthood." This finding further implies that governments should focus on investing in basic education to encourage individuals to invest in education during their adult life.

When the government is included in the model, the initial human capital stock becomes a function of government investment in basic education as a share of GNP (ε) is:

$$H = \varphi\varepsilon \tag{47}$$

where $\varphi > 0$ is constant and represents the marginal productivity of government investment with regard to the human capital stock. The government finances investments in basic education through a flat tax rate on the income of individuals; in periods 2 and 3, i.e. $\varepsilon = \tau$. The individual's consumption in each period is then given by:

$$c_t = [(1-h)\varphi\varepsilon](1-\varepsilon) \tag{48}$$

$$c_{t+1} = [\varphi\varepsilon + h](1-\varepsilon) \tag{49}$$

The solution to the utility maximization problem then becomes:

$$h = \frac{(\beta/\varphi\varepsilon)^{(1/\theta)}\varphi\varepsilon - \varphi\varepsilon}{1 + (\beta/\varphi\varepsilon)^{(1/\theta)}\varphi\varepsilon} \tag{50}$$

This result points to the finding that when $\theta < 1$, the number of hours spent on accumulating human capital is negatively related to government spending on basic education, which seems to contradict the result obtained earlier. This is because government investment in basic education is financed by a tax on the adult generation, crowding out private investment in education.

The authors define the workers' average level of schooling as:

$$H_a = \frac{\varphi\varepsilon + (\varphi\varepsilon + h)}{2} \tag{51}$$

Since population size is held constant, Teles and Andrade (2008) find economic growth to be proportional to the increase in the average level of schooling of workers:

$$\frac{\dot{Y}}{Y} = \frac{\dot{H}_a}{H_a} = \frac{\left[\varphi + \left(\frac{1}{2}\right)\left(\frac{dh}{d\varepsilon}\right)\right]}{[\varphi\varepsilon + (h/2)]}\dot{\varepsilon} \tag{52}$$

Theoretically, this result makes it impossible for the authors to affirm that an increase in government investment in basic education would necessarily increase the average number of years of schooling and, hence, economic growth. In fact, when the authors consider decreasing returns to the human capital stock and its accumulation ($\theta < 1$), the average level of schooling increases by less than government investment in education, which suggests a possible negative or negligible relationship between public education investment and economic growth. The authors suggest that such a relationship may arise because the income taxation needed to finance high levels of government investment in basic education distorts individual's incentives to pursue higher education.

Sequeira and Martins (2008) analyze the effects of government education subsidies in an endogenous growth model with human capital accumulation and unemployment. Intuitively, the results of their theoretical exercise show that subsidies directly enhance growth through human capital accumulation, but also increase equilibrium wages, leading to higher unemployment. Hence, subsidies through their negative effect on unemployment decrease the productivity of human capital accumulation and thereby deter growth. Moreover, education subsidies are also found to have negative impacts through related taxation. This leads the authors to determine the conditions under which subsidies stimulate economic growth, conditional on the level of unemployment.

Sequeira and Martins (2008) consider an economy populated by P individuals, each endowed with h human capital units and one unit of time supplied in elastically. The total level of human capital is given by:

$$H = hP \tag{53}$$

The production technology has a Cobb-Douglas form:

$$Y = K^{\alpha}H^{1-\alpha}L^{1-\alpha} \tag{54}$$

where L stands for the employment rate as all individuals are assumed to belong to the labour force.The human capital accumulation equation depends positively on employment as follows:

$$\dot{H} = (bL)I_S - \delta H \tag{55}$$

where I_S denotes education investments and parameter b measures its efficiency. Employment can also be defined as $(1 - u)$, where u is the unemployment rate.

Individuals maximize a CES utility function subject to:

$$Y = C + I_S + I_K - sI_S + tY \tag{56}$$

where $s$is the subsidy rate, i.e. the percentage of spending on education financed by the government.

Solving the consumer optimization problem and combining it with the profit maximization problem, Sequeira and Martins (2008) obtain the following equilibrium human-to-physical capital ratio:

$$\left(\frac{H}{K}\right)^{*} = \frac{bL}{\alpha}\frac{(1-\alpha)}{(1-s)} \tag{57}$$

This equation specifies the first effect of subsidizing education: it increases the equilibrium human-to-physical capital ratio. Assuming that subsidies are financed by a tax on output($t = sI_S/Y$) and based on the derived consumption growth equation, the authors obtain the following steady-state growth rate:

$$g_C^{*} = \frac{1}{\theta}\left[\frac{Y - sI_s}{Y}\alpha^{\alpha}(1-\alpha)^{1-\alpha}(1-s)^{-(1-\alpha)}b^{1-\alpha}(1-u)^{2(1-\alpha)} - \rho - \delta\right] \tag{58}$$

The authors distinguish two opposite effects of subsidies in this equation, for a given level of unemployment: a negative one ($-sI_S/Y$) and a positive one $(1 - s)^{-(1-\alpha)}$. Stating government education subsidies as a share of GDP $\left(\frac{sI_S}{Y}\right)$, yields:

$$g_C^{*} = \frac{A(1-s)^{\propto -1}(1-u)^{2(1-\alpha)} - \left(\frac{1-\alpha s}{1-s}\right)\delta - \rho}{\theta + (1-\alpha)\frac{s}{1-s}} \tag{59}$$

This equation describes the partial (i.e. given unemployment) relationship between education subsidies and economic growth. Sequeira and Martins (2008)

use this relationship to show that, under certain parameters/conditions, subsidies increase economic growth conditional on unemployment, where unemployment negatively impacts the effect of education subsidies on growth. More specifically, Sequeira and Martins (2008, p. 366) write:

> For sufficiently low subsidies rate, $s < \frac{\theta-1}{\theta-1+\alpha}$, and sufficiently low depreciation of capital $\rho > (\theta\text{–}1)\delta$, there is a positive effect of subsidies on economic growth rate, given the unemployment rate. Given that the partial effect of subsidies on growth is positive, the impact of higher unemployment is negative in that effect. This means that rising unemployment decreases the positive effect subsidies may have on growth.

Nelson-Phelps-Type Modelling

While Lucas (1988) considers a broad definition of human capital, in the sense that it can encompass the accumulation of knowledge and abilities to apply knowledge productively, Nelson and Phelps (1966) consider a more narrow human capital concept by specifically focusing on the impact of education on technological change. As Aghion and Howitt (1998, p. 338) write, "Nelson and Phelps (1966) provided a first attempt at modelling the idea that a major role for education is to increase the individual's capacity, first, to innovate (i.e. to create new activities, new products, new technologies) and, second, to adapt to new technologies, thereby speeding up technological diffusion throughout the economy."

In the approach of Nelson and Phelps (1966), education has a permanent effect on technological change and this effect drives sustained long-run growth. According to Nelson and Phelps (1966), the Lucas (1988) approach to modelling education as a direct factor of production amounts to "a gross misspecification of the relation between education and the dynamics of production" (Nelson and Phelps 1966, p. 75). Instead, Nelson and Phelps (1966) propose that education exerts an indirect effect on the production function of an economy through the rate of technological change.

A rising stock of human capital benefits growth by supporting the economy's ability to innovate and adopt new technologies. This implies that differences in the levels of human capital (instead of differences in the growth rates of human capital as suggested by Lucas (1988)) cause differences in output growth across countries. Hence, unlike in Lucas (1988), the growth rate of an economy depends on the level of technology A, and the growth rate of technology depends on the stock of human capital, which is viewed as a key input in the generation of new ideas and innovations. For any given country, Nelson and Phelps (1966) specify the following technological growth equation:

$$A(t) = \Phi(h)[T(t) - A(t)] \tag{60}$$

where h is the current human capital stock in an economy, such that $\Phi(h)$ represents educational attainment a in the country. $T(t)$ denotes the frontier technology which grows over time at a constant exponential rate λ, $T(t) = T_0 e^{\lambda t}$. The term $[T(t) - A(t)]$

represents the gap between the theoretically possible and actually used production technologies.

First, assuming exponential growth of *T(t)* and a positive *h*, Nelson and Phelps (1966) postulate that the rate of growth in production technologies actually used in an economy, i.e. $\frac{\dot{A(t)}}{A(t)}$, falls to λ at the limit, independent of educational attainment. Second, the gap between theoretically possible and actually used technologies, in the equilibrium, is a decreasing function of educational attainment. In this way, increased educational attainment increases the long-run trajectory of technology actually used in the economy. Both of these results constitute the solution to the equation specified in Eq. 60, given exponential growth of *T(t):*

$$A(t) = \left(A_0 - \left[\frac{\Phi}{\Phi + \lambda}\right]T_0\right)e^{-\Phi t} + \frac{\Phi}{\Phi + \lambda}T_0 e^{\lambda t} \tag{61}$$

This implies that the equilibrium path of technology actually used in the economy is given by:

$$A^*(t) = \frac{\Phi(h)}{\Phi(h) + \lambda}T_0 e^{\lambda t} \tag{62}$$

and the equilibrium gap between the theoretically possible and actually used technologies is given by:

$$\frac{T(t) - A^*(t)}{A^*(t)} = \frac{\lambda}{\Phi(h)} \tag{63}$$

Hence, in a technologically stagnant economy (defined as $\lambda = 0$), the gap approaches zero even when *h* is positive. In a technologically progressive economy ($\lambda > 0$), there is a positive equilibrium gap for every *h* and λ. The equilibrium gap is increasing in λ and decreasing in *h*. The elasticity of the long-run equilibrium level of technology actually used *A*(t)* with respect to *h* is increasing in *λ*. This indicates that returns to educational attainment are greater in a more technologically progressive economy. According to Nelson and Phelps (1966, p. 75), this result suggests that "society should build more human capital relative to tangible capital the more dynamic is the technology".

As Aghion and Howitt (1998, p. 354) observe, both the Lucas and Nelson-Phelps approach to modelling education in growth model simply different long-run growth effects. Namely, education may have a growth effect (Lucas) or a level effect (Nelson-Phelps) on the economy. They write, "what is at stake is whether raising the level of human capital will have either a once-and-for-all effect on output or increase its growth rate effect forever." However, Aghion and Howitt (1998) emphasize that it is plausible for both theoretical approaches to be true, with the difference being more semantic than real. They argue that an increase in the level of

human capital brings about an increase in output (Nelson-Phelps approach) and this is brought about through an increase in transitional growth rates (Lucas approach).

Romer (1990) presents a major extension of the Nelson-Phelps approach to modelling education within endogenous growth models. As this model is widely studied in both undergraduate and graduate macroeconomic textbooks, it will be unnecessary to reproduce the equations of the Romer (1990) model. However, there are three crucial assumptions in Romer (1990) worth stressing: constant returns to scale, free entry in the intermediate goods sector, and the non-rivalry of knowledge. The two basic equations of the Romer's (1990) model are:

$$Y = H_Y^{\alpha} L^{\beta} \int_0^{\infty} A x(i)^{1-\alpha-\beta} di \tag{64}$$

$$\dot{A} = B H_A A \tag{65}$$

where H_Y denotes human capital devoted to final output and the $x(i)$'s are imperfectly substitutable intermediate inputs in production. In the production function for ideas, H_A denotes human capital employed in research, B denotes the rate at which new ideas are discovered and A represents the 'stock of varieties' of ideas. Thus, new ideas are produced using both human capital employed in research and the stock of earlier ideas.

Due to constant returns to scale in the research sector, the model's growth solution exhibits a scale effect such that an increase in the population growth rate increases the supply of labour in research, which in turn increases research output and hence the steady state growth rate:

$$g_A = n \tag{66}$$

where n denotes the rate of population growth, which is equivalent to the growth rate of the number of researchers.

However, such a scale effect may not be present in developing countries. Jones (2002) disagrees with Romer's (1990) idea that the productivity of researchers grows over time, generating sustained long-run growth even if the number of researchers remains constant. He challenges the assumption of constant returns to scale in the research sector and shows that the effect of huge R&D expenditures on growth even in advanced OECD countries is practically nil. Instead, Jones (2002) proposes the existence of diminishing returns to the stock of ideas.

The possibility of diminishing returns is considered in a recent study conducted by Papageorgiou and Perez-Sebastian (2006). The authors build an R&D non-scale growth model that includes endogenous human capital and technological progress. They consider innovation and imitation as two of the main sources of technological progress, while formal schooling is considered as the main source of human capital.

The model economy of Papageorgiou and Perez-Sebastian (2006) consists of identical infinitely-lived individuals, and grows exogenously at rate n. Individuals in the economy can produce consumer goods, pursue education and conduct R&D.

In each period, individuals allocate their one unit of time endowment between working and studying. Output is produced via Cobb-Douglas technology:

$$Y_t = A_t^{\xi} H_{Yt}^{1-\alpha} K_t^{\alpha}, 0 <\propto< 1, \xi > 0 \tag{67}$$

where A_t is the economy's level of technology, ξ is the technology-output elasticity, H_{Yt} is human capital and K_t is private capital.

The economy's technological level evolves according to the following equation:

$$A_{t+1} - A_t = \mu A_t^{\varphi} H_{At}^{\lambda} \left(\frac{A_t^*}{A_t}\right)^{\psi} - \delta_A A_t, \varphi < 1, 0 < \lambda \leq 1, \psi \geq 0, A_t^* \geq A_t \tag{68}$$

where δ_A represents the technology depreciation rate. H_{At} is the portion of human capital employed in the R&D sector at time t. The worldwide technology frontier A_t^* grows exogenously at rate g_{A*}, μ is a technology parameter, φ weighs the effect of the stock of existing technology on R&D productivity and λ captures decreasing returns to R&D efforts.

Following Nelson and Phelps (1996), the R&D technology equation allows for a 'catch-up' term, $\left(\frac{A_t^*}{A_t}\right)^{\psi}$, which captures the idea that the greater the technology gap between the most technologically advanced country and the least technologically advanced country, the higher the potential of the latter to catch up through imitation of existing technologies. The parameter ψ represents the adoption barrier. Together, the production function and the R&D technology equation reflect complementarity between technology and human capital.

In specifying the human capital technology, Papageorgiou and Perez-Sebastian (2006) follow Bils and Klenow (2000) who suggest that the Mincerian specification of human capital is the appropriate way to incorporate years of schooling into the aggregate production function. In this regard, aggregate human capital is given by:

$$H_{jt} = e^{f(St)} L_{jt} \tag{69}$$

where L_{jt} is the total amount of labour allocated to sector j and S_t is the average educational attainment of labour in period t. The derivative $f'(S)$ represents the return to schooling estimated in a Mincerian wage regression: an additional year of schooling raises a worker's efficiency by $f'(S)$. Average educational attainment is expressed as:

$$S_t = \frac{\sum_{j=1}^{t-1} L_{Hj}}{L_t} \tag{70}$$

where L_t denotes population size and L_{Ht} denotes the total amount of time allocated to schooling in period t. The law of motion for average educational attainment is as follows:

$$S_{t+1} - S_t = \left(\frac{1}{1+n}\right)\left(\frac{LH_t}{L_t} - nS_t\right) \tag{71}$$

Thus, the evolution of S across time depends on the share of people in education L_H/L and the population growth rate. The steady-state solution to the model suggests that, along the balanced growth path, the economy invests in sufficient human capital to provide new generations with precisely the steady-state level of educational attainment. Moreover, the steady state growth rate of output is:

$$G_{Y,ss} = G_{C,ss} = G_{K,ss} = (1+n)^{\lambda\xi/[(1-\alpha)(1-\varphi)]} \tag{72}$$

Consistent with Jones (2002), the derived balanced growth path is free of scale effects, and policy has no effect on long-run growth. This occurs despite the presence of a formal schooling sector. This is because the mean years of education S_t reaches a constant level in the steady state.

Empirical Evidence

The literature studying the relationship between education, growth and poverty is overwhelming. Lucas' (1988) assertion that unbounded long-run growth can be achieved as long as human capital grows infinitely has posed a challenge for applied researchers faced with interpreting such a broad concept of human capital. For the most part, applied researchers have used a variety of proxies to measure human capital such as years of schooling, enrollment ratios, school completion rates, literacy rates, and many others. One of the most commonly used measures of human capital in the empirical literature is educational attainment, or the level of education. The findings of this literature are virtually unanimous and suggest three important conclusions. First, education positively impacts growth and reduces poverty. Poverty reduction is achieved not only through education's positive impact on future earnings, but also through a wide range of non-economic benefits ranging from personal empowerment to improved health. The second consistent finding is that returns to investments in education seem to be lower than returns to other types of public investments (such as in physical infrastructure and agricultural R&D). Thirdly, individual returns to education are much higher for those with higher levels of education.

This section reviews a selection of studies that analyze the growth and poverty impacts of education investments, especially in developing countries. It finds that the varying measures of human capital used in the empirical studies do not alter the main conclusions they reach.

Using a regional level panel dataset for 1977–1999, Fan et al. (2008) estimate the marginal returns to different types of government investments, in terms of growth and rural poverty reduction in Thailand. Their results show that public investment

in rural primary education have the third largest impact (after investments in agricultural research and rural electrification) on agricultural productivity and poverty reduction. The return to rural primary education investments is significant, such that 4.09 Thai baht are gained for each baht invested. In terms of poverty effects, the results indicate that for every million baht invested in rural education, 77 poor persons are lifted out of poverty. The poverty effect mainly operates through the positive effect of rural education on agricultural productivity.

Using district level data for 1992, 1995 and 1999, Fan and Zhang (2008) estimate the effects of different types of government investments on agricultural growth and rural poverty in Uganda. As in the case of Thailand, they find that government investments in education rank third in their impact on agricultural productivity and poverty reduction (after spending on agricultural research and road investment).In terms of productivity effects, for the country as a whole, investments in education are estimated to have a benefit-cost ratio of 3, suggesting that each additional shilling invested at the margin would yield three shillings. In terms of its poverty impact, public investments in education are estimated to bring 12.8 poor persons out of poverty for every million shillings invested. The authors suggest that this poverty-reducing effect of education investments arises mainly from improved agricultural productivity, higher non-farm employment and increased rural wages.

Fan et al. (2000) estimate the impact of different types of government spending on agricultural growth and rural poverty reduction in India using 1970–1993 state level data. They find that government education spending has the third largest marginal impact on rural poverty and productivity growth, after investment in rural roads and agricultural research. An additional one million rupees invested in education raises 41 people above the poverty line. Greater nonfarm employment opportunities and increased wages are found to be the main factors contributing to reduced poverty. The authors also find that if the government were to increase its investment in education by Rs100 billion (at 1993 constant prices), the incidence of rural poverty would be 0.22 % lower.

Using household survey data, Fan et al. (2005) carry out a similar empirical exercise for the case of Tanzania. They find that every shilling invested in education by the government leads to a nine shilling increase in average household incomes. The estimated returns to investment in education are found to rank third after investments in agricultural research and road investment. However, the poverty effect of public investment in education ranks first, with every million shillings invested bringing 43.1 persons out of poverty.

Using 1970–1997 provincial level data for the case of China, Fan et al. (2002) find that government expenditures on rural education significantly contribute to an increase in the average years of schooling of the rural population (15 years of age and older), such that for every 1 % increase in government spending on rural education, the average years of schooling of the rural population increases by 0.34 %. Average years of schooling of the rural population is found to have a positive and significant effect on agricultural and non-agricultural productivity, rural non-farm wages and non-farm employment. The authors further find that total public investment in education had by far the largest poverty-reducing effect, such

that for every 10,000 yuan invested, 8.8 poor people were lifted above the poverty line; this is 30 % more than comparable R&D investments, which had the second largest poverty-reducing effect. Increased rural nonfarm employment accounts for much of this poverty-reducing effect. In addition, education is found to have the second largest returns to agricultural GDP and the third largest return to both nonfarm GDP and overall rural GDP. These findings lead the authors to conclude that investment in education presents the dominant "win-win" strategy.

Psacharopoulos and Patrinos (2002) find a pattern of falling returns to education by level of economic development and level of education. Their study emphasizes that investment in education behaves very similarly to investment in physical capital. According to their figures, in developed economies, the returns to education tend to decline as education investments expand. However, private returns to higher education in low- and middle-income countries are high, at 26 % and 19.3 % respectively. The authors note that private returns to education are always higher than social returns because of the extent of public involvement in the education sector. In addition, among the three levels of education (primary, secondary and tertiary), primary education exhibits the highest social returns as well as the highest private returns in all low-income, middle-income and high-income economies. This is attributed to the existence of broad positive externalities relating to primary education, such as improved public health.

Concluding Remarks

This literature review has sought to assess various strategies employed in modelling infrastructure and education within the theoretical endogenous growth literature. It has also summarized empirical findings regarding the impact of education and infrastructure on economic growth and poverty alleviation, particularly in developing countries.

Overall, this literature review finds that the theoretical studies modelling infrastructure within endogenous growth models, whether as a flow or a stock variable, tend to disregard the indirect effect that infrastructure has on some measure of output via TFP. In terms of the empirical findings, it finds that most studies have examined the impact of infrastructure on economic growth and poverty alleviation through the use of individual, physical measures of infrastructure stocks. The findings of these studies demonstrate that growth and poverty impacts of infrastructure can be substantial, but they vary across different types of infrastructure capital. For instance, investments in roads and irrigation are found to have sizeable direct and indirect effects on economic growth and poverty reduction, while the impact of electricity is less clear.

In contrast to approaches to modelling infrastructure, endogenous growth theorists who model education have not only considered the direct impact of education on output by specifying human capital accumulation as a factor input, but have also considered education's indirect impact on output via technological change. The

empirical literature in this area overwhelmingly shows that public investments in education have a positive and significant impact on growth and poverty reduction, particularly in developing countries. However, the returns to public investments in education are consistently found to be lower than the returns generated by investments in infrastructure.

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The Growth and Distributive Impacts of Public Infrastructure Investments in the Philippines

Erwin Corong, Lawrence Dacuycuy, Rachel Reyes, and Angelo Taningco

Introduction

The government of the Philippines continues to implement reforms that aim to promote economic development and lift the country's standard of living. This is critical as it has been lagging behind neighbouring East Asian countries with respect to economic size and per capita income.[1] The bottlenecks the country faces include poor physical infrastructure (transport and utility infrastructures), low quality of education, volatile economic growth, high poverty rates and large income disparities.

Various business surveys have pointed to the relatively poor quality of transportation infrastructure in the country, such as airports, maritime ports, roads and railroads. Energy and water infrastructures have also not been fully developed, and concerns over a possible crisis in power and water have recently mounted. Public

[1] Based on the World Bank's World Development Indicators database 2009 Philippine GDP, at constant 2000 prices and adjusted for purchasing power parity (PPP), stood at US$295.8 billion. This is lower than in most other East Asian countries, including the People's Republic of China or PRC (US$8.2 trillion), Indonesia (US$877 billion), Japan (US$3.8 trillion), Republic of Korea (US $1.2 trillion), Malaysia (US$348.2 billion) and Thailand (US$491.8 billion). This contrasts with the situation, in 1980, when Philippine PPP-adjusted real GDP was US$126 billion, much higher than Malaysia (US$67.3 billion) and Thailand (US$105.4 billion). Moreover, the PPP-adjusted GDP per capita at 2005 prices for the Philippines was US$3,216, lower than in the PRC (US $6,200), Indonesia (US$3,813), Japan (US$29,688), Korea (US$25,493), Malaysia (US$12,678), Singapore (US$45,978) and Thailand (US$7,258).

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J. Cockburn et al. (eds.), *Infrastructure and Economic Growth in Asia*,
Economic Studies in Inequality, Social Exclusion and Well-Being,
DOI 10.1007/978-3-319-03137-8_3,

spending on education has also been criticized as being low compared to neighbouring countries in the region, resulting in a weak public education system.

Against this backdrop, the government of the Philippines has engaged in policy measures to improve the quality of public infrastructure (especially in relation to transport and utilities) and public education in order to ensure and sustain robust growth and to alleviate poverty. To speed up public infrastructure development in the presence of fiscal constraints, the government has revived the promotion of partnerships with the private sector (in Build-operate-transfer schemes), with the private sector providing financial and technical expertise for selected infrastructure projects.

This paper contributes to policy analysis in the Philippines by providing a quantitative assessment of the growth and distributive impacts of increasing spending on public infrastructure, such as in transportation, utilities and education. Since these issues are interlinked, a computable general equilibrium (CGE) model is employed together with a micro-simulation model in order to trace the channels whereby public infrastructure investments filter through the Philippine economy. We use Philippine data in a dynamic CGE model developed by Dissou and Didic (2011) which explicitly models public capital as an input in firms' production process. The results of the CGE simulations are then used as inputs into a micro-simulation module following Cockburn, Duclos and Tiberti (2011) in order to assess the distributive impacts of an increase in public infrastructure investments.

To provide input to policy makers, we conduct two experiments to assess the potential immediate, short-run and long-run effects of increased public investment expenditures, when financed by either higher taxes or foreign borrowing. The policy focus of this paper leads us to stay within the confines of attainable government policies by simulating a 25 % permanent increase in the public infrastructure expenditures-to-GDP (PIE-GDP) ratio over time. This increase is sufficient to achieve the government's minimum target of a 5 % PIE-to-GDP ratio.

The next sections are as follows. Section "Public Infrastructure" provides a brief survey of the public investment literature and the section "Public Infrastucture Challenges" discusses issues relating to public infrastructure in the Philippines. Section "Philippine Poverty Profile" presents a poverty profile of the Philippines. Section "Methodology" describes the CGE model and the micro-simulation module, then sections "Policy Experiments" and "Simulation Results" respectively explain the simulation scenarios and the simulation results. Finally, the section "Summary and Insights" provides insights and conclusions.

Public Infrastructure

Empirical research on the economic impact of public infrastructure is now widespread. One strand in the literature makes use of econometric modeling techniques. In a seminal paper, Aschauer (1989) uses an OLS approach to show that the capital stock of public infrastructure is a determinant of total factor productivity in the

United States. Isaksson (2009) adopts a panel data regression model—using ordinary least squares (OLS), both fixed and random effects, and instrumental variables—to analyze a group of 57 advanced and developing countries over 1970–2000. His research finds that public capital has a relatively strong impact on industrial development and that public capital growth has the strongest impact on rapidly growing economies and high-income economies.

Calderon and Chong (2004) use a generalized method of moments (GMM) dynamic panel estimation model to capture the role of the volume and quantity of infrastructure—particularly in energy, public works, railways, roads and telecommunications—on income distributions in a set of 101 countries over 1960–1995. Their study reveals a negative relationship between the level of infrastructural development and income inequality. Arslanalp, Bornhorst and Gupta (2011) use a production function with estimated public capital in 48 advanced and developing economies over 1960–2001. They find that increases in the stock of public capital are associated with economic growth, with advanced economies registering stronger short-run effects and developing economies having greater long-run effects. Gupta et al. (2011) adopt a production function approach with a GMM estimation. They use efficiency-adjusted public capital stock data for 52 developing countries, and find that this type of public capital has a significant effect on output.

Other related studies have opted for general equilibrium techniques. Zhai (2010) uses a global CGE model, and finds that regional infrastructure investment in developing Asia would raise global income by US$1.8 trillion by the year 2020, with 90 % of the gains accruing to the region. Moreover, such investment would help boost global and regional trade. Dissou and Didic (2011) use a CGE model with heterogeneous agents and public capital in a multi-sectoral and intertemporal environment calibrated to the economy of Benin. They show, among other things, that: increasing public investment has short-run Dutch disease effects, expected to be offset by increased productive capacity in the long run; higher public infrastructure spending benefits non-constrained agents more than constrained agents; and that the short-run private sector investment response depends on how the public infrastructure is financed.

Unfortunately, empirical research on the role of infrastructure spending on economic growth and poverty in the Philippines—a developing economy in Southeast Asia—is limited. Teruel and Kuroda (2005) use a translog cost function and find that improvements in public infrastructure in the Philippines—particularly road infrastructure—are instrumental in enhancing agricultural productivity in the country. Savard (2010), using a top-down bottom-up computable general equilibrium (CGE) micro-simulation model, demonstrates the macro, sectoral and poverty impacts of increasing public investment in the Philippines. The findings indicate that: public investment positively impacts GDP and employment; the macro effects do not differ substantially across the three public investment financing mechanisms considered (income tax, value-added tax (VAT) and foreign aid); public investment lowers poverty—the magnitude being strongest under VAT; and foreign aid is the most equitable funding mechanism.

A contentious empirical issue is the estimation of the elasticity of output to public capital, which has been criticized in several studies as being too high, as a result of some methodological limitations or weaknesses. Isaksson (2009) points out that this concern arose because Aschauer's (1989) estimate of the effect of public investment is impossibly large, ranging from 0.38 to 0.56, implying an annual rate of return of no less than 100 %. Potential sources of this problem vary and those cited in the literature include endogeneity, reverse causality (from output growth to public capital), spurious correlation (due to non-stationarity of the data), omitted state-dependent variables and lack of agreement regarding the appropriate rate of return from public investment.

Furthermore, it has been conjectured that the large estimates on the elasticity of output to public capital could emanate from: high public investment (as a proportion of GDP), a situation which is prevalent in highly corrupt countries, as corruption tends to inflate public investments; from unproductive uses in public capital; and from the composition of public capital. Several papers have attempted to correct for these econometric and conceptual problems by accounting for the elasticity of output to public capital, including Arslanalp, Bornhorst and Gupta (2011), Gupta et al. (2011) and Isaksson (2009).

Public Infrastucture Challenges

It has been widely perceived that Philippine transport infrastructure—air transport, ports, railroads, roads—is of poor quality and has not improved much in recent years. The latest World Economic Forum's (WEF 2010) Executive Opinion Survey, published in its Global Competitiveness Report (GCR) 2010–2011, ranked the Philippines 113th out of 139 countries in the overall quality of its infrastructure, giving the country a score of 3.2 (the possible score ranges from 1 [worst] to 7 [best]). More specifically, the Philippines ranked 97th in railroad infrastructure, 112th in air transport infrastructure, 114th in road infrastructure and 131st in port infrastructure. This suggests that, by international standards, the overall quality of Philippine infrastructure is relatively poor. Indeed, Fig. 1 confirms that, between 2004 and 2010, infrastructure indicator scores deteriorated slightly in relation to air transport, ports and railroads, while the score on road infrastructure remained unchanged.

Infrastructure Trends

The road network in the Philippines expanded during the 1990s, then began to deteriorate, falling to 200,037 km in 2003 (the most recent data available) from 202,123 km a year earlier. The proportion of paved roads in the national road

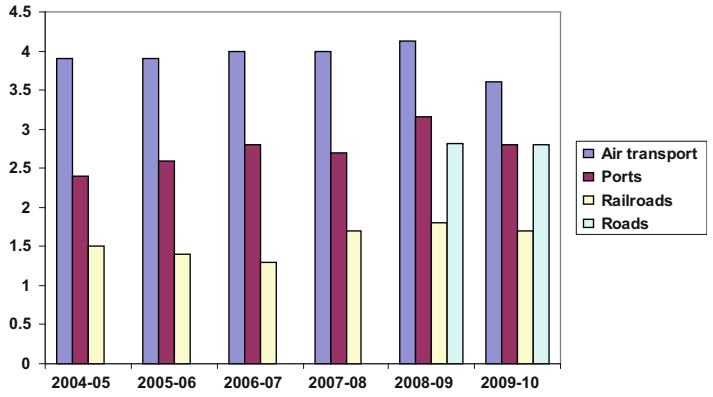

Fig. 1 World Economic Forum's Executive Opinion Survey scores on transport infrastructure indicators in the Philippines, 2004–2010 (Source: World Economic Forum, Global Competitiveness Report, various issues)

network climbed during the mid-1990s, rising to 19.8 % in 1998, but then fell to 9.9 % in 2002. The length of rail lines stagnated between 1990 and 2008: the country had 479 km of rail in the early 1990s, a number that increased to 491 km by 2004 and eventually fell back to 479 km by 2008.

The Philippines also ranked relatively low (101st of 139 countries) in the 2010–2011 WEF Executive Opinion Survey in terms of the quality of electricity supply, garnering a score of 3.4 (the possible score ranges from 1 [insufficient] to 7 [sufficient and reliable]). Concerns over a looming power shortage or crisis in the country were evident in 2010 amid intermittent power outages, particularly in the southern part of the archipelago (Mindanao), as widespread droughts caused by El Nino—which resulted in receding water reservoirs in hydroelectric dams—coupled with poor maintenance work, have led to inadequate power supply. At that same time, the disruptive weather had resulted in surging peak demand (DOE 2010). Moreover, structural reforms in the power sector have faced bottlenecks, and not enough new power capacity has come online in the country. Obstacles to power sector reforms include delays in the privatization of the government's power generation assets—such as power plants, particularly those from the state-owned National Power Corporation—hampering the rehabilitation of these assets and limiting the participation of the private sector in the electricity supply industry.

Moreover, power supply in the Philippines is geographically concentrated in a few areas, further contributing to the problem of inadequate power capacity. In a recent assessment of the Philippines' power situation, the Department of Energy (DOE) of the Philippine government reported that: (i) In the country's Luzon

region, the power generation capacity has been concentrated in the Northern and Southern areas, with relatively large power loads in Metro Manila and neighbouring provinces; (ii) Power generation capacity in the Visayas region has been concentrated in the Leyte-Samar grid; and (iii) In Mindanao, most of the power generation capacity is located in the Northern areas but the bulk of electricity demand comes from the Southern areas.

As electricity demand continues to increase (see Appendix 1, Fig. 14), there is an urgent need to create more energy-related infrastructure in order to increase the country's power generation capacity. Over 2010–2013, the DOE together with power firms plan to build four coal-fired plants across the archipelago. Furthermore, the DOE has projected that the Luzon, Visayas and Mindanao power grids would respectively need an additional capacity of 11,900 megawatts (MW), 2,150 MW and 2,500 MW of capacity by 2030.[2]

Access to water seems to have marginally improved over the years in the Philippines (see Appendix 1, Fig. 15). The proportion of the overall population in the country with access to an improved water source has climbed gradually, from 84 % in 1990 to 87 % in 1995, 88 % in 2000, 90 % in 2005 and 91 % in 2008. Urban dwellers generally have better access to an improved water source than those in rural areas. The share of the urban population with access to an improved water source remained unchanged at 93 %, while the situation improved consistently in rural areas from 76 % in 1990 to 87 % in 2008.

Despite improved water access, there is still a need for the Philippine government to further expand water distribution and improve water infrastructure. The government has admitted that there are certain challenges in the water sector such as: water depletion in major cities, including Metro Manila and Metro Cebu; rampant water pollution; increasing demand for water; low willingness to pay for water; low cost recovery of investments; and institutional problems.

Government Policy on Infrastructure

The Philippine Infrastructure Public-Private Partnership (PPP) program is the flagship policy agenda of the government in promoting infrastructure development in the country. The PPP recognizes the private sector's role as a catalyst of growth and as an important source of infrastructure financing. Infrastructure projects covered by the PPP program include those that aim to develop the agri-business, educational, energy, environment, health, industry, information and communications technology, logistics, property, transportation, telecommunications and water supply sectors.

[2] Ibazeta (2010).

Table 1 Breakdown of Philippine infrastructure investment (by sector, 2009–beyond 2013, billions of pesos)

Sector	2009	2010	2011	2012	2013	Beyond 2013
Transportation	123.8	247.6	133.2	102.2	63.6	171.9
Power	85.5	196.2	246.9	150.9	94.7	230.3
Water	36.5	68.8	68.2	112.2	49.6	179.2
Telecommunications	7.9	9.8	7.3	15.5	15.0	0.5
Social infrastructure	43.8	279.1	40.8	31.2	24.7	26.0
Support to ARC's	23.5	22.0	58.4	247.3	55.7	3.3
Re-lending programs	5.0	9.0	10.2	11.3	4.3	13.4
Total	326.0	832.6	564.9	670.7	307.6	624.7
% of GDP	4.1	9.2	5.8	6.9	3.2	6.4

Source: National Economic and Development Authority (NEDA) and authors' computation
Note: 2011 nominal GDP data is used to get the share of infrastructure investment for 2012, 2013, and beyond 2013
ARCs agrarian reform communities, *GDP* gross domestic product

The Medium Term Philippine Development Plan (MTPDP) 2004–2010 reported that the Philippine government will prioritize transportation infrastructure-related projects that boost the country's trade and investments. These projects include construction of roads and railroads that will decongest the country's capital (Metro Manila), major highways, roads and airports connecting tourism hubs, and roll-on roll-off (RORO) ports. The government aims to boost infrastructure spending in the country through the Comprehensive and Integrated Infrastructure Program (CIIP). The CIIP anticipates that the private sector would bring PHP400.9 billion in infrastructure financing, with PHP214.4 billion in the transport sector, PHP112.3 billion in water supply, PHP70.7 billion in social infrastructure and PHP3.5 billion in telecommunications.[3]

Table 1 shows the annual sectoral breakdown of planned infrastructure investment in the Philippines starting in 2009 and through to 2013 and beyond. Total planned infrastructure spending in 2011 is 32.2 % lower than in the previous year, at PHP564.9 billion (5.8 % of GDP); the power sector was expected to have the largest allocation at PHP246.9 billion (43.7 % of total), followed by the transportation sector at PHP133.2 billion (23.6 % of total). Infrastructure investments are planned to be 18.7 % higher in 2012 on a year-on-year basis, at PHP670.7 billion (6.9 % of GDP), and the largest chunk of investments (36.9 %) in 2012 was to be targeted to government support for agrarian reform communities (ARCs). In 2013, the government plans lower infrastructure investments of PHP307.6 billion (3.2 % of

[3] Paderanga (2010).

GDP), with the power sector receiving the greatest share of the total, at PHP94.7 billion (30.8 % of total). Beyond 2013, it is estimated that about PHP625 billion (6.4 % of GDP) will be spent on infrastructure, with power, water and transportation being the largest recipients.

In 2010, the Philippine government's expenditures (excluding interest payments and spending on financial services) totalled PHP1,379.3 billion, of which 36.3 % were on goods and services from production sectors, 33.8 % on social services, 24.5 % on general public services and 5.3 % on national defence.[4] The largest single focus of public spending was education, at 17.4 % of public spending (PHP240.6 billion), followed by transport and telecommunications infrastructure (12.6 %, PHP174.3 billion). However, public spending on health-related infrastructure and on electricity/energy-related infrastructure were both relatively small, respectively at 3.7 % (PHP50.9 billion) and 1.3 % (PHP17.8 billion).

Philippine Poverty Profile

Based on official accounts disseminated by the National Statistics Coordination Board (NSCB) of the Philippine government, the poverty incidence (estimated using per capita income data) among the Philippine households in 2009 was estimated at 26.5 %, which is higher than the previously estimated poverty incidences of 26.4 % in 2006 and 24.9 % in 2003. Philippine economic growth fluctuated during this period, with real GDP growth of 1.1 % in 2009, 5.2 % in 2006 and 5.0 % in 2003. More recently, in April 2013, the NSCB reported that the poverty incidence among the whole population for the first semester of 2012 stood at 27.9 %, somewhat lower than the 2009 and 2006 first semester figures of 28.6 % and 28.8 %, respectively. Moreover, income inequality in the country declined somewhat during this period, with the Gini coefficient falling from 0.465 in 2003 to 0.458 in 2006 and slipping further to 0.448 in 2009.

Snapshot of Philippine Poverty

We now provide a description or characterization of poverty based on explicit subgroup characteristics in order to highlight the regional variation and urbanity

[4] Inclusive of interest payments (PHP276, 212.0 million) and payments for financial services (PHP6, 994.7 million), public expenditures of the Philippines in 2010 totalled PHP1, 662.5 billion.

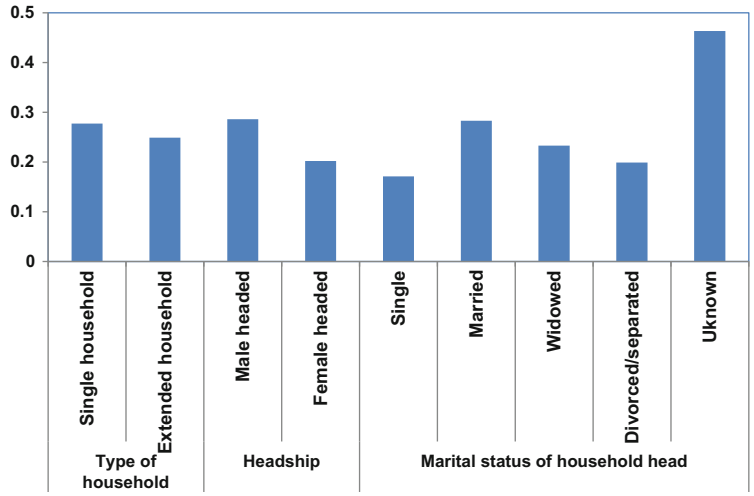

Fig. 2 Poverty incidence based on type of household, sex and marital status of household head (Source: Authors' computation based on Philippine FIES 2006 (overall))

differences of poverty estimates by using survey estimation techniques.[5] In constructing profiles, we consider the following attributes: (1) headship; (2) economic activities of the household head which include occupation and class of work; (3) marital status of household head; and (4) the type of household.

We estimated the poverty incidence for each of the household attributes based on data from the 2006 Family Income and Expenditure Survey (FIES) (the full results are shown in the Appendix 2, Table 9). Figure 2 presents the poverty incidence by household type, and sex and marital status of the household head. It shows that single households or nuclear families have a higher poverty incidence (27.7 %) than extended households (24.9 %); this may be due to the fact that extended households have more access to resources, giving rise to relatively more reliable safety nets. This is consistent with the findings of Albert and Collado (2004) which were based on the 2000 FIES. We also find that roughly 29 % of male-headed households are poor, whereas about 20 % of female-headed households are poor. By marital status of the household head, the lowest poverty incidence is found among single-parent households at 17.1 %, followed by households whose head is divorced (19.9 %),

[5] We computed estimates by using the survey's total estimation module which allowed us to compute for the total number of poor and non-poor households. The sampling weights that we use pertain to probability weights assigned to respective households. The stratifying variable that we use combined information on the province and urban/rural residence.

whereas households whose heads are married have a higher poverty incidence (28.3 %).

Estimates of poverty incidence by class of worker (household head) and number of household members employed are likewise presented in Table 9 in the appendix. The literature generally finds a strong relationship between poverty status and involvement in economic activities. Our results show that households are more likely to be poor when the head is self-employed and are less so if the head works for the government. Our calculations also show that households with heads working in the public sector have a lower poverty incidence compared with households whose heads are working in the private sector. This can be easily explained by the fact that, on average, civil servants earn more, and more stable, income than those working in the private sector.[6] The incidence of poverty among self-employed household heads is higher than among those employed in the private sector. In fact, households whose heads are self-employed have the highest poverty incidence, at 34.7 %; this is somewhat expected since a significant portion of the workforce is employed in the informal sector, which is dominated by unincorporated businesses. Finally, households with eight employed members have a relatively lower poverty incidence than those with less than eight employed members.

Methodology

A combination of computable general equilibrium (CGE) and micro-simulation methodologies is employed to understand how public infrastructure investments impact on the Philippine economy. We now briefly present the models and underlying data.

The CGE Model

We employ a dynamic general equilibrium model developed by Dissou and Didic (2011) to trace the channels via which public infrastructure investments filter through the Philippine economy. To avoid repetitiveness, we only summarize the salient features of the model and refer the interested reader to Dissou and Didic (2011) for a more complete model specification.[7] In general, the model assumes a

[6] However, we do not have evidence that private sector workers with comparable attributes relative to government workers have better compensation.

[7] For more details of the model, please see Dissou and Didic (2011).

small open economy—consisting of households, firms and the government—that produces and consumes tradable and non-tradable goods and has access to the international capital market.

An important feature of this model is that it explicitly treats public capital as an input into the firms' production process, and thus allows us to quantify the growth and distributive effects of public infrastructure investments on the Philippine economy over time.

Public capital is assumed to be a pure public good[8] and enters firms' production functions as an externality that enhances output. This is because the accumulated flows of public infrastructure investment generate positive externalities in the production of goods and services by firms. Although data limitations restrict the analysis to the effects of the public capital stock as a whole, productivity effects of public infrastructure are allowed to vary across industries. Firms in all industries make use of intermediate inputs, labour, physical capital and public capital to produce a composite output that can be sold in both domestic and international markets. However, public capital is a fixed input—as it is a decision variable at the discretion of the government rather than of the firm—while other inputs are controlled by the private sector.

The economic intuition behind the impact of public infrastructure on economic growth in the model is as follows. In a scenario with fixed public capital and increased supply of other inputs—such as labour, physical capital and intermediate inputs—the productivity of labour and physical capital would deteriorate, thereby hurting economic growth. For example, physical capital accumulation alongside labour supply growth can result in negative externalities such as traffic congestion and deteriorating infrastructure quality if not accompanied by higher investments in public infrastructures. In order to mitigate these negative effects on the productivity of private inputs and to spearhead economic growth, the stock of public capital must increase through investments in public infrastructures.

As shown in Fig. 3, gross output is determined via a three-stage process. The lowest stage involves the optimal determination of labour and private capital through a constant elasticity of substitution (CES) function. The CES labour-private capital aggregate is then combined with public capital through another CES function to form a composite value added. In spite of the CES aggregator formulation, the stock of public capital is a fixed factor with endogenous rates of return reflecting its marginal product. Note that public capital is not a decision variable for the firm since public capital stocks are accumulated through public sector infrastructure investments. Finally, gross output is determined by combining the composites of value added and intermediate inputs (a Leontief function of individual intermediate inputs) through another CES function.

[8] As a pure public good, services derived from public capital are not subject to congestion.

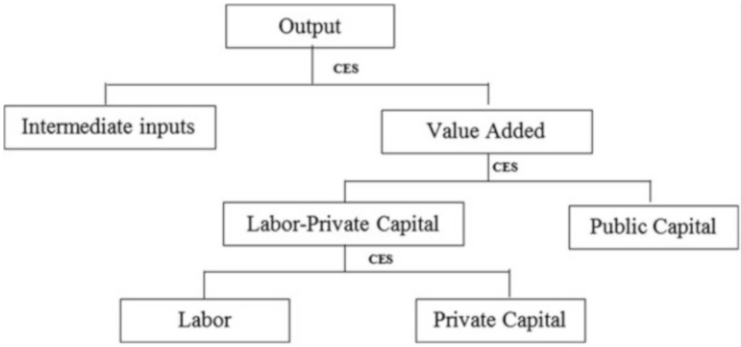

Fig. 3 Production structure

Another salient feature of the model is that it accounts for firm and household heterogeneity. Households are divided into two types according to their access to credit markets: (a) constrained (myopic) households do not have access to credit markets. These households consume out of their current income, and at the same time save a constant and strictly positive fraction of their disposable income (Keynesian savings behaviour); and (b) non-constrained (forward-looking) households have access to credit in the capital market, where they can borrow and lend at a fixed world interest rate. These households are thus able to smooth consumption over time. Regardless of the household type, we assume that household labour supply is perfectly inelastic, implying that households do not consider leisure as part of their labour supply decision. Household income sources are: wages, capital income (returns from both private and public capital) and transfers from the government and from the rest of the world. Finally, all households consume on the basis of a constant elasticity of substitution (CES) function.

Firms are also classified into two types according to their access to the credit market. Non-constrained firms have access to capital markets where they can borrow and lend at a fixed world interest rate and are owned by non-constrained households. These firms determine their optimal levels of inputs and outputs through intertemporal optimization. Constrained firms do not have access to capital markets and are exclusively financed by constrained households who use their savings to purchase the capital stock of these firms. In contrast to non-constrained firms, constrained firms only maximize current profits. The government collects income taxes directly on the labour income of both non-constrained and constrained households and from the dividends of non-constrained households.

Real government spending on commodities is exogenous but grows overtime as a function of population growth and technological progress. The current public infrastructure-to-GDP ratio is exogenous. We treat this ratio as a policy variable that can be modified to perform simulations in relation to increased public infrastructure. Government savings is held fixed to ensure that the public sector cannot increase its debt over time. Higher public investment in infrastructure is either

financed by a uniform increase in production tax rates imposed on all firms or through an increase in foreign financing, with payments to the latter being part of foreign debt service payments in each period. The labour market behaves in a neo-classical manner and wages adjust to ensure equilibrium in labour markets. Similarly, commodity prices adjust to maintain equilibrium in the goods markets. Total investment is financed by total savings: investment in constrained firms is financed from the savings of constrained households; while dividends paid by non-constrained firms to non-constrained households are net of investment expenditures. In addition, the transversality condition imposed on asset holdings ensures that the country cannot continuously increase its foreign debt, i.e., any increase in debt today must be paid for by future increases in the current account balance. Finally note that the fixed government savings provide the macro closure.

CGE Data and Parameters

The model uses an aggregated version of the latest available unofficial social accounting matrix (SAM) for the Philippines (Cororaton and Corong 2009) as its principal database. There are 12 sectors in the model: (1) crops and livestock; (2) other agricultural products; (3) food, alcoholic beverages, and tobacco; (4) mining; (5) paper and wood; (6) petrochemicals; (7) textiles and garments; (8) heavy manufacturing; (9) light manufacturing; (10) other manufacturing; (11) public services; and (12) other services. Three sectors are assumed to be comprised of constrained firms: other agriculture, other manufacturing and other services; the rest are comprised of non-constrained firms.

Table 2 presents the basic structure of the Philippine economy in the base scenario, following the country's SAM. Of the 12 sectors, the light manufacturing sector is observed to contribute the largest share to the country's value added and to total investment, exports and imports. The other services sector accounts for the largest share of final consumption.

Table 3 summarizes the CES elasticities for the production structure illustrated in Fig. 6. Due to an absence of econometric estimates, we assume conservative elasticities taken from estimates in the literature on developing countries. Note that, although the assumed production elasticity of substitution found in the first three columns of Table 3 are the same for all sectors, their relative shares are different. Relative shares are of greater importance than elasticity values as the simulation results are driven more by the structure of the economy than by the differences in the choice of elasticity parameters.

Similarly, the last two columns of Table 3 show the elasticities for the CES-Armington function (substitution between imports and domestic sales) and the CET function which reflects substitution between exports and domestic sales. These values were taken from the GTAP database.

Table 2 Characteristics of Philippine economy (based on 2000 Philippine SAM)

	Value added	Consumption	Investment	Government	Exports	Imports
Crops and livestock	4	3.5	4.5	0	1.2	1.9
Other agriculture	0	3.2	0.1	0	0.8	0
Food, beverage and tobacco processing	2	19.9	0.4	0	3.6	4.1
Mining	0.2	0.1	0	0	0.4	9
Paper and wood	1.7	0.7	0.3	0	2.1	1.8
Petrochemical	1.1	3.7	0.2	0	2.6	7.4
Textiles and garments	1.1	3.2	0.2	0	9.5	5.2
Heavy manufacturing	1.4	0.1	0.6	0	2.7	4.7
Light manufacturing	85.3	3	48.6	0	59.5	47.9
Other manufacturing	3.2	1	2.7	0	3	2
Public services	0	0.1	0	100	0.1	0
Other services	0	61.6	42.4	0	14.6	16

Source: Authors' computations
SAM social accounting matrix

Table 3 Parameters for CGE model (based on 2000 Philippine SAM)

	Gross output	Value added	Labour-private capital	CES Armington	CET
Crops and livestock	0.5	0.4	0.4	2.3	2.3
Other agriculture	0.5	0.4	0.4	2.8	2.8
Food, beverage and tobacco processing	0.5	0.4	0.4	2.3	2.3
Mining	0.5	0.4	0.4	2.8	2.8
Paper and wood	0.5	0.4	0.4	2.1	2.1
Petrochemical	0.5	0.4	0.4	1.9	1.9
Textile and garment	0.5	0.4	0.4	2.3	2.3
Heavy manufacturing	0.5	0.4	0.4	2.8	2.8
Light manufacturing	0.5	0.4	0.4	3.0	3.0
Other manufacturing	0.5	0.4	0.4	2.8	2.8
Public services	0.5	0.4	0.4	1.9	1.9
Other services	0.5	0.4	0.4	2.6	2.6

Source: Authors' computations
SAM social accounting matrix

Microsimulation Module

A top-down CGE microsimulation procedure is employed by using the results of the CGE simulations as inputs into a microsimulation module in order to assess the distributive impacts of higher public infrastructure investments. The microsimulation module, which is based on Cockburn, Duclos and Tiberti (2011), uses the 2006 Family Income and Expenditure Survey (FIES) of the Philippines.

For brevity, we only summarize the microsimulation procedure (for details see Cockburn et al. 2011). Per capita consumption in real terms for the base year and

the simulation periods is the variable of interest for estimating poverty and inequality changes across the different scenarios. According to the methodology followed in this study, this variable is affected by the change in consumer prices as well as in household revenues, here corresponding to incomes from wage and self-employment activities. Consistently with the CGE model, we also took into account the different marginal propensity to consumption for constrained and non-constrained households.

Initially, the FIES is processed to classify constrained and non-constrained households. A logit model specifies the probability of being a non-constrained household ($Y_i = 1$; $Y_i = 0$ if constrained), which is defined as: has access to formal credit institutions, has saved or has a savings account. The logit model shown in Eq. 1 estimates the probability that a given household h is non-constrained ($p_{h,nc}$). By implication, the complement of $p_{h,nc}$ gives the probability that a given household h is constrained ($p_{h,c}$).

$$Logit(\pi_h) = \alpha + \beta_v X_h + \epsilon_h \text{ with } \pi_h = E(Y_h|X_h) \tag{1}$$

where vector X_h includes the V community and household socio-economic characteristics of household h: household's region and urban/rural residence, whether the household head receives a fixed payment from work activities, the occupational category the household head belongs to, the natural logarithms of real per capita household consumption, household size, household head's gender and age, as well as the educational level of the household head and the household head's age squared.

Passing to labour activities, we considered one single category of worker (which is perfectly mobile across all sectors) and we made the hypothesis of full employment. This is in accordance with CGE model's hypotheses. As for revenues, revenues for wage workers that reported missing incomes have been estimated by a standard Heckman selection approach. Then, the change in the wage rate as predicted by the CGE model has been used to simulate the variation in the wage component across the different scenarios. Changes in revenues from self-employment activities (included the component for own-consumption) were derived from the variations in the sectoral (value of the) value-added as simulated by the macro model. It is noteworthy here that the CGE results (concerning the quantities variables) are provided in terms of productive worker, then taking into account the change in population, labour force and technology over time.

To observe changes in household consumption levels following variations in the prices of goods and household income, the nominal consumption for each good is converted into real terms. Using a Cobb-Douglas utility function, which lays on the hypothesis of fixed budget share, real or equivalent per capita consumption is:

$$e_{h,d,t} = \frac{y_{h,d,t}}{\Gamma_{h,d,t}} \text{ with } \Gamma_{h,d,t} = \prod_{k=1}^{K} \left(\frac{p_{k,d,t}}{p_{k,D,0}} \right)^{w_{h,d,k}} \tag{2}$$

where $y_{h,d,t}$ is the total nominal per capita expenditures of each household h living in district d at time t; $\Gamma_{h,d,t}$ is the household-specific consumer price deflator which takes into account both spatial (by comparing district d to the reference cluster D—here, the capital region NCR) and temporal (by comparing time t to the reference time 0) price differences; $p_{k,D,0}$ is the reference unit price, which corresponds to the price of good k at time 0 estimated in the reference district D; $p_{k,d,t}$ is the unit price at time t for good k in cluster d; $w_{h,d,k}$ is the budget share for good k by household h in district d. As for the economic sectors, we mapped the categories of consumption commodities in the underlying micro and macro data and then aggregated by nature of goods in order to have the same type of aggregates in the two models.

To be consistent with the household classifications in the CGE model, the micro-simulation procedure takes into account the differences in savings and consumption of all households, particularly non-constrained households which can change their savings rate over time (in contrast to constrained households whose savings rate remains fixed). Nominal per capita consumption for a household $y_{h,d,t}$ at time t is calculated as:

$$y_{h,d,t} = y_{h,d,t=0} + \sum_{k=1}^{j} \left(\Delta R^{k}_{h,d,t} p_{h,nc} (1 - s_{nc,t}) + \Delta R^{k}_{h,d,t} p_{h,c} (1 - s_c) \right) \qquad (3)$$

where $y_{h,d,t}$ is defined as the sum of per capita consumption of household h in the base year ($y_{h,d,t=0}$) and the per capita changes in the k revenue components (R), namely wage and non-wage incomes. As already stated, changes in these sources are taken from the CGE simulation results and plugged into the micro module. As defined by Eq. 3, changes in the revenue sources are weighted by the probability of household h being non-constrained $p_{h,nc}$ (and the complementary situation of being constrained). Only the shares devoted to consumption are retained for consumption: $(1-s_{nc,t})$ for non-constrained households and $(1-s_c)$ for constrained households, where $s_{nc,t}$ and s_c are the saving rates for the two types of households.

Poverty effects are measured using the Foster-Greer-Thorbecke (FGT) $P\alpha$ class of additively decomposable measures (Foster et al. 1984). Let $z_{D,0}$ be the real poverty line, that is, a line measured in terms of the reference prices $\mathbf{p}_{D,0}$. The FGT family index is then defined as:

$$P_{\alpha}(z) = \frac{1}{\mathbf{N}} \sum_{h=1}^{H} \rho_{h,d} n_{h,d} \left(\frac{z_{D,0} - e_{h,d,t}\left(\mathbf{p}_{k,D,0}, \mathbf{p}_{k,d,t}, y_{h,d,t}\right)}{z_{D,0}} \right)^{\alpha}_{+} \qquad (4)$$

where $f_{+} = \max(0, f)$, $\mathbf{N}$ is the number of households in the survey (and corresponds to the sum of the sampling weights), $n_{h,d}$ is the size of the household h, $\rho_{h,d}$ is the sampling weight of h, and α is a parameter that captures the "aversion to poverty" or the distribution sensitivity of the poverty index.

The FGT poverty measure depends on the values that the parameter α takes. We calculate the poverty headcount for $\alpha = 0$. The poverty headcount is the proportion of the population that falls below the poverty line. When $\alpha = 1$, the poverty gap

indicates how far the poor are from the poverty line on average. Finally, when $\alpha = 2$, the severity of poverty is measured as the squared average distance of income of the poor from the poverty line. The severity index is more sensitive to the distribution among the poor because the poorest of the poor in the population are weighted more heavily.

Inequality is calculated using the Gini coefficient, which is the most commonly used measure of inequality. It computes the average distance between cumulative population shares and cumulative income shares (Duclos and Araar 2006). The Gini coefficient is calculated as:

$$Gini \equiv I(2) = \int_0^1 (p - L(p))\kappa(p;2)dp \tag{5}$$

where *L(p)* is the cumulative percentage of total income held by the cumulative proportion p of the population (ranked by increasing income) and k represents the percentile-dependent weights.

Policy Experiments

Using the CGE model described in the section "The CGE Model," we conduct two policy experiments to assess the potential effects of higher public investment in infrastructure financed by: (1) international lending with a concessional interest rate of 6 %; and (2) higher production taxes. In order to stay within reasonable limits of attainable government policies we simulate a 25 % permanent increase in the public infrastructure expenditure-to-GDP (PIE-to-GDP) ratio relative to the baseline. This increase is sufficient to achieve the government's minimum PIE-to-GDP ratio target of 5 %.

As mentioned in the section "Public Infrastructure", a contentious empirical issue is the estimation of the elasticity of output to public capital. Given the absence of econometric estimates for the Philippines, we assume a conservative exogenous elasticity of output to public capital of 0.15 %—a lower-end estimate that is consistent with most empirical studies. This conservative value was chosen to account for concerns that large estimates of the output elasticity of public capital could emanate from high public investment (as a proportion of GDP)—as corruption tends to inflate public investments, from unproductive uses in public capital and from the composition of public capital. However, we undertake sensitivity analysis to determine the robustness of the estimated economic and poverty impacts to changes in the assumed elasticity of output to public capital.

Other variables that are exogenously determined in the model include the annual population growth rate (1.8 %), the foreign concessional lending rate (6 %), and the depreciation rate of the public and private capital stocks (15 %, respectively). Using base year values from the SAM, in conjunction with exogenously given parameter

values and the transvertality condition, we calibrate and solve the dynamic CGE model to reproduce the baseline path of the economy over a 50-year time horizon. The Business as Usual (BaU) scenario is then used to make comparisons with the counterfactual simulation results. Note that, in the BaU, all real variables are expressed in efficiency units and all prices are held constant.

Simulation Results

We analyze the economy-wide effects of higher public investment in infrastructure at the aggregate and the sectoral level encompassing three time frames: the immediate period (first year), the short-run (fifth year) and the long-run (twentieth year). Since investments made in the current year only become fully operational in the following year, we first discuss the demand-side effects of an increase in the PIE-to-GDP ratio in the immediate period. We then discuss the demand-side and the supply-side effects arising in the short-run and the long-run. Note that all results are presented as percentage deviations from the economy's baseline trajectory. Presenting results this way allows us to isolate the economy-wide effects arising from higher public investment.

Scenario 1: 25 Percent Increase in the PIE-to-GDP Ratio (International Financing)

Macroeconomic effects: The macroeconomic results of scenario 1—a 25 % increase in the PIE-to-GDP ratio financed by international lending at concessional interest rates—are shown in the first three columns of Table 4. An increase in public infrastructure investment financed by international borrowing immediately leads to real exchange rate appreciation (1.6 %), and thereby improves the purchasing power of the Philippine economy.

As a result, in the first year, imports rise by 2.6 %, as the appreciation of the real exchange rate immediately induces substitution away from domestically produced consumer and capital goods to the relatively cheaper imported consumer and capital goods. The appreciation of the real exchange rate further leads to a significant reduction in exports (2.8 %) in the first period, as they become relatively more expensive in the international market.

At the same time, total investment increases by 6.4 % which is 1.4 percentage points more than in the scenario where an increase in the production tax finances higher public infrastructure expenditures. Higher total investment in the current scenario in the immediate period is primarily due to an expansion in private investment. In fact, in the current scenario, private investment rises by 0.8 % in the first year following increased public investment in infrastructure, while it falls by 0.6 % in the scenario where production taxes finance higher public investment in

Table 4 Macro-economic results (percent deviations from baseline)

	International financing			Production tax financing		
	First	Short run	Long run	First	Short run	Long run
Real GDP	−0.1	1.5	2.9	−0.2	0.9	2.0
Wage rate	1.0	3.6	6.5	−1.0	1.5	4.1
Price of investment good	1.0	0.6	0.2	0.4	0.2	0.0
Total investment	6.4	7.7	8.2	5.2	6.6	7.1
Public investment	25.6	27.1	28.7	25.2	26.5	27.8
Private investment	0.8	2.0	2.3	−0.6	0.9	1.2
Constrained	1.4	1.7	1.9	−0.5	−0.2	0.1
Non-constrained	0.5	2.3	2.5	−0.6	1.5	1.8
Total household consumption	2.2	2.5	2.7	0.2	0.4	0.6
Constrained	2.4	2.3	2.0	−0.1	0.0	0.1
Non-constrained	1.9	2.7	3.3	0.6	0.8	1.1
Total exports	−2.8	−0.7	2.0	−1.2	1.0	3.5
Total imports	2.6	3.0	3.5	1.0	1.9	2.5
Real exchange rate[a]	−1.6	−0.9	−0.5	−0.6	−0.5	−0.4
Foreign saving	0.9	0.4	−0.3	0.8	0.4	−0.2
Total capital stock[a]	0.0	3.8	8.2	0.0	3.3	7.2
Public capital stock[a]	0.0	13.5	27.5	0.0	13.3	26.6
Private capital stock[a]	0.0	0.7	2.1	0.0	0.1	1.0
Constrained[a]	0.0	0.8	1.8	0.0	−0.2	0.1
Non-constrained[a]	0.0	0.7	2.3	0.0	0.3	1.6
Disposable income of constrained households	2.4	2.3	2.0	−0.1	0.0	0.1
Labour income	1.0	3.6	6.5	−1.0	1.5	4.1
Capital income	2.7	4.3	5.3	−0.1	2.0	3.5
Government revenue	8.4	9.6	10.9	6.9	8.3	9.6
Increase in production tax rate (%)	–	–	–	27.0	24.9	22.4
Additional international borrowing (% of GDP)	1.1	1.1	0.9	–	–	–

Source: Authors' computation based on simulation results

[a]A positive sign indicates a depreciation of the real exchange rate

infrastructure. Hence, in the absence of an increase in production taxes, domestic firms are able to increase their profitability through higher capital goods production and higher accumulation of the private capital stock.

Furthermore, in the first period, the price of investment goods rises by 1 %—the highest increase of all periods considered in this scenario—because the productivity-enhancing effects of public infrastructure investments do not start to materialize until after the first year. Recognizing that increasing productivity arising from public infrastructure investment will lead to higher returns on investment in the future, non-constrained firms, in the first year, increase their level of investment by less than constrained firms (0.5 % vs. 1.4 %).

As well, total household consumption increases by 2.2 % in the first period, which is 2 percentage points more than in the scenario where production taxes

finance increased public infrastructure investment. This is because consumption of both constrained and non-constrained households rises by 2.4 % and 1.9 %, respectively. Two factors drive this result. First, the appreciation of the real exchange rate makes imported goods relatively cheaper, thereby inducing higher consumption. Second, higher household income arising from increasing returns to labour and capital provides an additional boost to household consumption.

However, in the first period, real GDP falls by 0.1 % as the negative demand-side effects, at least in the immediate period, outweigh the positive demand-side effects of increased public infrastructure investment. Namely, the increases in private investment and household consumption experienced in the first year following higher public infrastructure investment are not sufficiently high enough to offset the stronger demand for imported goods and the considerable decline in exports. However, as a result of increased private investment and household consumption, the magnitude of the fall in the real GDP in the first period is lower than in the scenario where public infrastructure investment is financed by increased production taxes.

The positive, demand-side effects of higher public infrastructure investment strengthen in the short-run and the long-run as a result of ongoing private capital accumulation and improving productivity. In fact, when public infrastructure investment is financed by international borrowing, the economy is able to accumulate more private capital stock than in the case where this investment is financed by production taxes. Specifically, the total stock of private capital expands by 0.7 % and 2.1 %, respectively in the short-run and the long-run in the current scenario, compared with 0.1 % and 1 % in the production tax scenario.

The disposable income of constrained households rises further in the short and the long-run, respectively by 2.3 and 2 %. This is largely due to the increase in these households' labour income (which rises by 3.6 % in the short-run and by 6.5 % in the long-run) and to an increase in their capital income (which rises by 4.3 % in the short-run and 5.3 % in the long-run). Higher incomes in turn lead to higher total household consumption, which grows by 2.5 % and 2.7 % over the short-run and the long-run.

Investments by constrained firms rise by 2 % in the short-run and by 2.3 % in the long-run, while investments by non-constrained firms increase by 3.8 % and 8.2 % over these time frames. Similarly, total investment in the short and the long-run grows by more in this scenario (7.7 % and 8.2 %) than in the production tax scenario, as higher public investment is complemented by a rise in private investment.

Over time, the stronger real exchange rate appreciation resulting from the continuous inflow of international financing results in slower export growth and accelerated import growth (See Fig. 4). Although exports eventually recover due to the productivity-enhancing effects of additional public infrastructure, long-run potential export growth is somewhat lower than observed in the baseline. Heightened import demand and weakened exports demand are the primary reasons behind a deteriorating trade balance over time, which is exactly opposite to the situation observed in the production tax financing scenario. Nevertheless, public

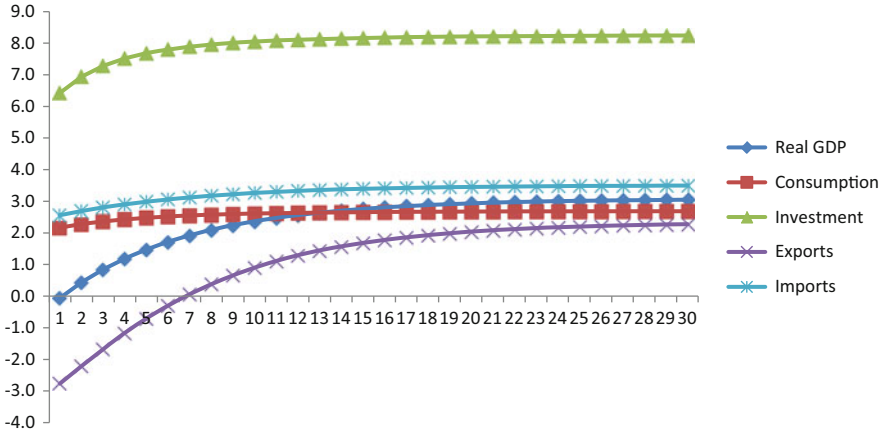

Fig. 4 GDP: demand side effects (international financing) (Source: Authors' computation based on simulation results)

infrastructure investment when financed by international lending still exhibits stronger positive economic effects over time, as reflected by the increase in real GDP in the short-run (1.5 %) and the long-run (2.9 %) than when it is financed by increased production taxes (Fig. 4).

Sectoral effects: We now analyze the sectoral effects of a 25 % rise in the PIE-to-GDP ratio financed by international lending (Table 5). Exports fall in every sector in the immediate period (by at least 1.1 % in the petro-chemicals sector and by at most 6.4 % in the other manufacturing sector) as the appreciated real exchange rate leads to a loss in all sectors' competitiveness in the international market. Similarly, in the first period, imports increase substantially in every sector (by at least 0.3 % in the mining sector and by at most 5.1 % in the other manufacturing sector), as domestic consumers substitute domestic goods for cheaper imported products. The real exchange rate appreciation, together with stronger demand for imported capital goods, boosts imports in the light manufacturing, heavy manufacturing and construction services sectors since these sectors provide inputs for (increased) public investment.

In the absence of a distortionary production tax, output expands in the crops/livestock, other agriculture, food processing, petrochemical and other services sectors (0.7 %, 0.3 %, 0.6 %, 0.1 % and 0.5 % respectively) in the immediate period following increased public infrastructure investment. Unfortunately, this is not the case for the textiles, light manufacturing, heavy manufacturing and other manufacturing sectors. In these sectors, output contracts in the first period due to the appreciation of the real exchange rate which makes imported capital goods (light and heavy manufacturing) relatively cheaper, causing domestic producers of these products to lose their competitiveness in the first year. Compared with the case

Table 5 Sectoral effects (Scenario 1: International financing, percent deviations from baseline)

	Crops, livestock	Other agriculture[a]	Food processing	Mining	Paper, wood	Petro-chemical	Textiles, garments	Heavy manufacturing	Light manufact.	Other manufact.[a]	Public services	Other services[a]
Gross output												
First	0.7	0.3	0.6	−0.9	−0.4	0.1	−1.0	−0.9	−1.5	−3.2	0.0	0.5
Short-run	1.9	1.6	1.8	0.9	1.1	1.5	0.0	1.1	−0.1	−0.4	0.0	1.9
Long-run	2.4	2.7	2.4	3.5	2.6	2.8	1.4	3.7	2.3	2.6	0.0	3.2
Employment												
First	1.0	0.7	0.8	−1.1	−0.5	−0.1	−1.2	−1.1	−1.7	−3.1	0.1	0.8
Short-run	0.8	0.5	0.6	−0.4	−0.2	0.2	−1.2	−0.3	−1.4	−1.6	−0.6	0.8
Long-run	0.2	0.2	0.0	0.8	0.1	0.2	−1.0	1.0	−0.2	0.1	−1.2	0.6
Investment (sector of destination)[b]												
First	3.4	0	3.0	−0.7	0.4	1.3	−2.0	−0.5	−2.7	0	0.4	0
Short-run	2.9	0	2.7	2.6	2.3	2.6	0.9	2.8	1.4	0	1.1	0
Long-run	2.7	0	2.6	3.6	2.7	2.8	1.6	3.7	2.6	0	1.3	0
Exports												
First	−3.0	−5.3	−3.0	−1.8	−2.1	−1.1	−2.1	−1.9	−2.4	−6.4	−2.2	−4.2
Short-run	−0.4	−1.0	0.0	0.4	0.1	0.9	−0.9	1.2	−0.9	−2.3	−4.4	−0.6
Long-run	0.3	2.8	1.5	4.0	2.3	2.8	0.8	5.3	1.9	2.0	−6.7	2.8
Domestic sales												
First	0.9	0.7	0.8	−0.8	−0.1	0.2	−0.3	−0.8	−0.3	−1.3	0.0	0.8
Short-run	1.9	1.8	1.9	1.0	1.3	1.5	0.6	1.1	1.0	0.7	0.0	2.1
Long-run	2.5	2.7	2.4	3.4	2.6	2.8	1.8	3.4	2.9	3.0	0.0	3.2
Imports												
First	4.9	7.0	4.8	0.3	2.0	1.6	1.5	0.3	1.9	5.1	2.2	6.2
Short-run	4.4	4.8	3.7	1.6	2.5	2.2	2.2	1.0	2.8	4.6	4.6	4.8
Long-run	4.7	2.6	3.4	2.8	2.9	2.8	2.9	1.6	3.8	4.0	7.2	3.6
Domestic demand												
First	1.1	0.7	1.1	0.1	0.3	0.6	0.2	−0.5	0.9	1.5	0.0	1.3
Short-run	2.1	1.8	2.0	1.5	1.5	1.7	1.1	1.1	2.0	2.5	0.0	2.3

Long-run	2.6	2.7	2.5	2.9	2.7	2.8	2.2	2.9	3.4	3.4	0.0	3.2
Consumption												
First	1.3	0.9	1.4	2.6	2.0	2.2	2.2	2.4	2.4	1.6	1.7	1.2
Short-run	1.9	1.9	2.1	2.7	2.3	2.5	2.3	2.7	2.5	2.1	0.8	2.0
Long-run	2.0	2.8	2.4	2.8	2.6	2.7	2.5	3.1	2.6	2.6	−0.2	2.6

Source: Authors' computation based on simulation results

[a]Constrained industries: investment from constrained firms, by sector

[b]These are constrained industries. Their Investments by sector of destination follow the baseline path

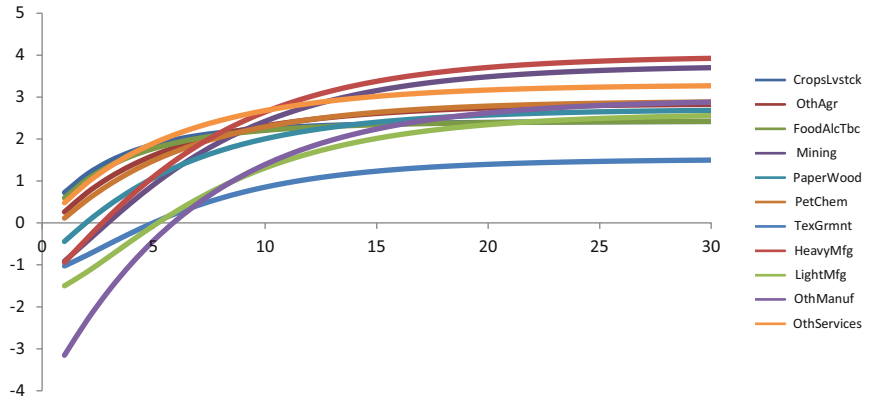

Fig. 5 Effects on output, by sector (international financing) (Source: Authors' computation based on simulation results)

where higher production taxes finance increased public infrastructure investment, total demand for goods and services from all sectors rises substantially. This is because of the stronger demand for cheaper imports and the effect of producers shifting towards the domestic market following exchange rate appreciation. This effect persists in the short-run and the long-run.

The long-run supply-side effects of higher public investment resulting from capital accumulation and improved productivity are felt by producers across the entire economy (See Fig. 5). Moreover, the increase in output across sectors is more or less similar given public infrastructure investment financed by international borrowing compared with that of production tax financing.

Over time, the positive spillover effects of higher public infrastructure investment enhance the competitiveness of domestic producers in the international market, supporting their export recovery (See Fig. 6). This contrasts with the results observed in the case of tax-financed public infrastructure investment. In that case, exports in the food processing sector and the petrochemical sector do not recover, even in the long-run. Instead, imports continue to outpace exports in the long-run due to the persistently higher real exchange rate (See Fig. 7).

As in the case where increased production taxes finance additional public infrastructure investment, all sectors experience an increase in investment in the long-run. Being an important producer of capital goods, heavy manufacturing registers an important expansion of investment in the short run (1.4 %) as well as in the long-run (2.6 %), resulting in substantial output and export growth over these time frames. Overall, public investment financed by international financing benefits

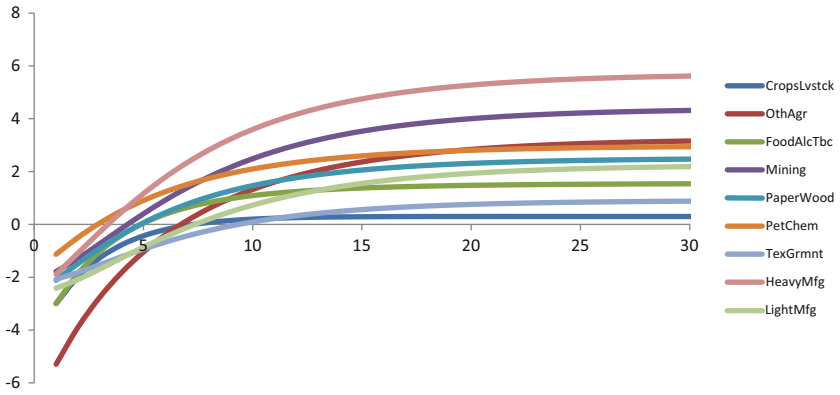

Fig. 6 Effect on exports, by sector (international financing) (Source: Authors' computation based on simulation results)

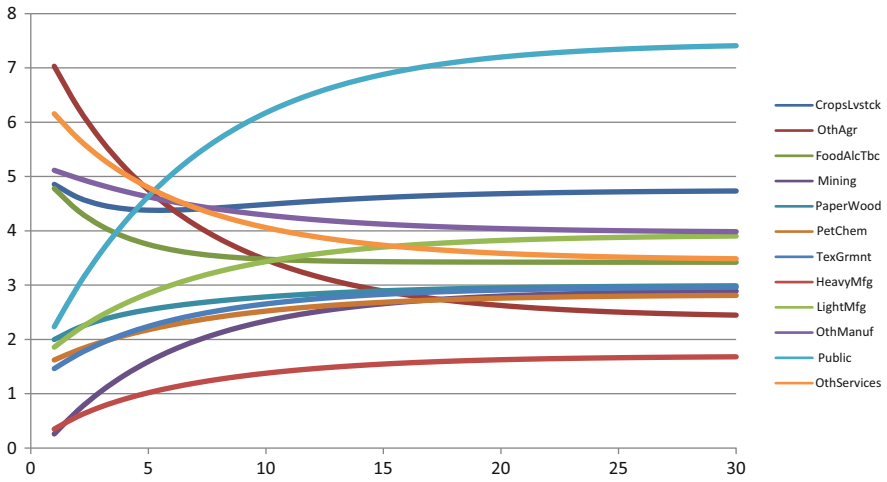

Fig. 7 Effect on imports, by sector (international financing) (Source: Authors' computation based on simulation results)

all sectors almost equally in terms of output expansion in the long-run. The reallocation of factors from the agricultural sector towards the heavy and light manufacturing sectors that is observed in the tax-financing case is absent in the current scenario.

Scenario 2: 25 Percent Increase in PIE-to-GDP Ratio (Production Tax Financing)

Macroeconomic effects: The macro-economic results of scenario 2—a 25 % increase in the PIE-to-GDP ratio financed by higher production taxes—are shown in the last three columns of Table 4. Total investment in the first year increases by 5.2 %, bolstered by the 25 % increase in public infrastructure investment. A slight reduction in total private investment of 0.6 % is indicative of the presence of a crowding-out effect. This immediate, negative crowding-out effect of tax-financed public infrastructure investment arises as a result of higher prices of investment goods (+0.4 %) and the higher production tax rate imposed on all firms. Total private investment thus falls: non-constrained firms decrease their level of investment marginally more (−0.6 %) than constrained firms (−0.5 %).

Furthermore, in the first period, imports rise by 1.0 % as higher public investment boosts demand for imported capital goods which become relatively less expensive than domestically produced goods. At the same time, exports fall by 1.2 % because domestic firms are less competitive on international markets due to the higher cost structures associated with higher production taxes. The combination of lower exports and higher imports results in real exchange rate appreciation of 0.6 % and a deterioration in the trade balance.

Surging demand for imported goods combined with falling exports and decreased private investment lead to a 0.2 % fall in real GDP in the first period following an increase in tax-financed public infrastructure investment. In fact, the rate of taxation on production rises by 27 %[9]—relative to the baseline—to finance the 25 % increase in the PIE-to-GDP ratio. The higher taxes impose an additional burden on firms in the economy, reducing their capacity to pay wages and to generate capital returns (−1.0 and −0.1 % respectively) to factor owners. Indeed, lower factor returns cause disposable income and consumption to fall marginally (−0.1 %) among constrained households; while the consumption of non-constrained households rises by 0.6 % in anticipation of increased future income.

The public capital stock increases substantially relative to the baseline scenario in both the short-run (13.3 % in 5 years) and the long-run (26.6 % in 20 years). The accumulation of public capital enhances the marginal productivity of private factor inputs—labour and private capital—over time, leading to increased real wages and higher capital income. As a result, disposable income of constrained households starts to rise over time to reach a slightly higher level than that recorded in the baseline scenario. It is worth noting that higher wages allow the government to collect more income taxes from households. Hence, the initially considerable rise in the production tax rate needed to finance the 25 % increase in the PIE-to-GDP ratio is dampened in the short and the long-run as higher income taxes help finance the

[9] Note: this figure represents the uniform percentage change in the effective production tax rates, and are not necessarily identical across industries. It is also worth mentioning that this increase is not as large as it may seem given that initial production tax ranges from 0.7 % in paper and wood to 9 % in petrochemical sector. The largest new production tax rate is, for example, 11.4 %.

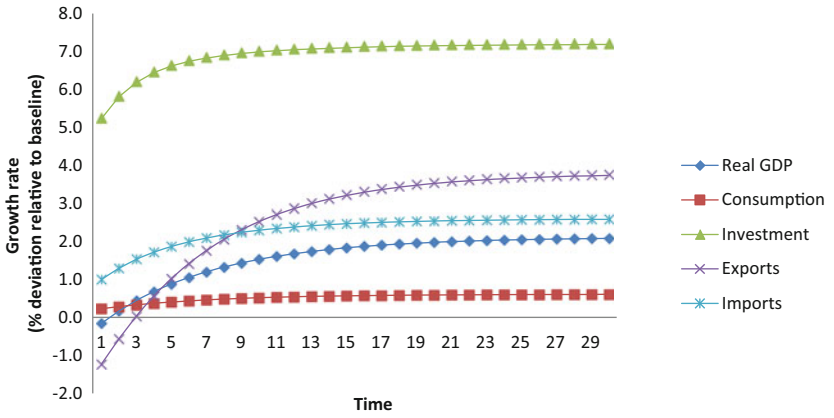

Fig. 8 GDP: demand-side effects (production tax financing) (Source: Authors' computation based on simulation results)

increase in public expenditures. Likewise, higher marginal productivity of private inputs mitigates the increase in the price of investment goods in the long-run, effectively incentivizing private sector investment.

Higher public investment bolsters the total stock of capital in the economy, and provides an impetus to private investment in both the short-run (6.6 %) and the long-run (7.1 %). This phenomenon of rising public and private investment over time appears to suggest that public infrastructure investments complement private sector investments, i.e., that a crowding-*in* effect takes place in both the short-run and the long-run. Since profitability is higher under improved productivity, both constrained and non-constrained firms undertake more private investment in the long-run. Non-constrained firms increase their level of investment by more than constrained firms because they anticipate future changes in capital productivity, whereas constrained firms increase their investment to a lesser extent due to the constrained expectations of their owners (constrained households).

Higher productivity helps reduce the burden of higher production taxes and supports improved competitiveness of domestic firms in the international market. This stimulates exports growth, which eventually outpaces import growth in the long-run. The real exchange rate appreciation observed in the first year tapers off in the short and the long-run. Moreover, the higher export growth helps improve the balance of trade. Total short- and long-run consumption respectively grow by 0.4 and 0.6 %, as consumption of both constrained and non-constrained households rises in line with increased income.

The net effect of these changes is a relative increase in real GDP of 0.9 % in the short run and 2 % in the long-run. This confirms that additional public infrastructure investments positively affect the economy of the Philippines through productivity and capital accumulation effects that begin to take hold in the short-run (Fig. 8).

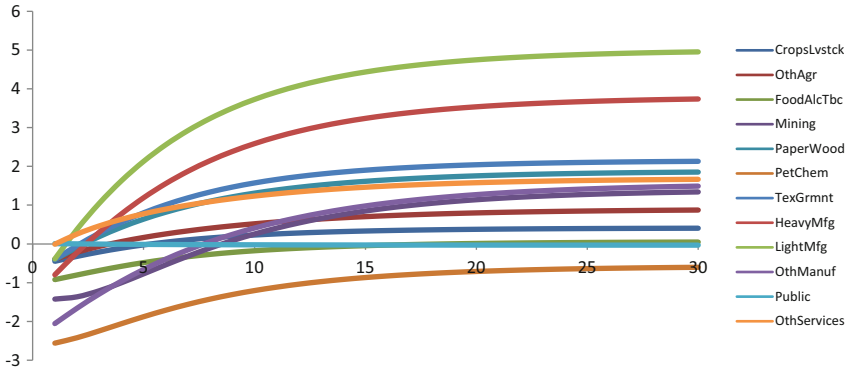

Fig. 9 Effects on sectoral output (production tax financing) (Source: Authors' computation based on simulation results)

Sectoral effects: In contrast to scenario 1, the direct consequence of using a higher production tax to finance public investments in capital infrastructure is a higher cost structure among firms, causing an immediate contraction in output in every producing sector of the economy (See Table 6). In the first period, exports fall significantly in each sector of the economy except in the public services sector as domestic firms lose their competitiveness in the international market. Moreover, the higher domestic cost structure together with increased demand for investment goods leads to a fairly substantial increase in imports, particularly in the light manufacturing (1.4 %), heavy manufacturing (1.7 %) and other services (1.9 %) sectors. Likewise, the food/beverage/tobacco sector registers a 1.8 % rise in imports as the domestic economy substitutes domestically produced goods for cheaper imported products.

In the first year, total domestic demand falls in most sectors, with the exceptions of the light manufacturing, heavy manufacturing and other services sectors, which are more heavily used in public investment. Domestic demand improves in all sectors in the short and the long-run, and this is particularly the case in the light manufacturing, heavy manufacturing and other services sectors (See Fig. 9). In the long run, the positive supply-side effects of higher public investment (capital accumulation and improved productivity) benefit all producers in the economy. This is particularly true for the light and heavy manufacturing, textiles and other services sectors, which register significant output growth in the long-run. Although relatively modest, many other sectors experience the same output expansion effect (crops and livestock, other agriculture, food/alcohol/tobacco). However, output in the food processing and petrochemical sectors remains below its baseline value in the long-run due to increased imports.

Table 6 Sectoral effects (Scenario 2: production tax financing, percent deviations from baseline)

	Crops, livestock	Other agriculture[a]	Food processing	Mining	Paper, wood	Petro-chemical	Textiles, garments	Heavy manufact.	Light manufact.	Other manufact.[a]	Public services	Other services[a]
Gross output												
First	−0.4	−0.4	−0.9	−1.4	−0.4	−2.6	−0.4	−0.8	−0.4	−2.1	0.0	0.0
Short-run	0.0	0.2	−0.5	−0.8	0.6	−1.9	0.8	1.2	2.1	−0.7	0.0	0.8
Long-run	0.4	0.8	0.0	1.1	1.8	−0.7	2.0	3.5	4.7	1.3	0.0	1.6
Employment												
First	−0.2	0.0	−0.4	−1.4	0.0	−2.1	0.0	−0.4	0.1	−1.6	0.3	0.5
Short-run	−0.8	−0.6	−1.0	−1.7	0.0	−2.4	0.2	0.5	1.5	−1.2	−0.2	0.2
Long-run	−1.4	−1.1	−1.6	−0.9	−0.1	−2.3	0.3	1.6	3.0	−0.4	−0.8	−0.2
Investment (sector of destination)												
First	−1.4	0.0	−1.9	−4.0	−0.1	−5.6	0.2	0.3	2.3	0.0	−0.1	0.0
Short-run	0.0	0.0	−0.2	−0.3	1.3	−1.4	1.7	2.8	4.3	0.0	0.7	0.0
Long-run	0.3	0.0	0.1	1.0	1.7	−0.6	2.0	3.5	4.9	0.0	0.8	0.0
Exports												
First	−0.6	−1.3	−3.3	−0.7	−0.3	−6.6	−0.3	−1.0	−0.9	−3.0	0.8	−1.6
Short-run	−0.4	0.2	−2.5	−0.3	1.2	−6.1	1.2	1.8	2.0	−1.6	−1.9	−0.3
Long-run	−0.1	1.8	−1.5	2.2	2.8	−4.3	2.7	5.5	5.0	0.7	−4.4	1.3
Domestic sales												
First	−0.4	−0.3	−0.8	−1.5	−0.4	−2.2	−0.4	−0.8	0.3	−1.5	0.0	0.1
Short-run	0.0	0.2	−0.4	−0.8	0.5	−1.5	0.5	1.1	2.3	−0.1	0.0	0.9
Long-run	0.4	0.7	0.1	1.0	1.5	−0.4	1.6	3.2	4.4	1.6	0.0	1.6
Imports												
First	−0.3	0.6	1.8	−2.4	−0.5	2.5	−0.6	−0.5	1.4	1.7	−0.7	1.9
Short-run	0.3	0.2	1.8	−1.4	−0.1	3.4	−0.1	0.4	2.7	2.3	1.9	2.0
Long-run	0.9	−0.3	1.7	−0.2	0.3	3.8	0.5	1.0	3.7	2.6	4.6	1.9
Domestic demand												
First	−0.4	−0.3	−0.6	−2.3	−0.4	−1.0	−0.5	−0.7	0.9	0.6	0.0	0.3
Short-run	0.0	0.2	−0.2	−1.3	0.4	−0.2	0.4	0.9	2.5	1.3	0.0	1.0

(continued)

Table 6 (continued)

	Crops, livestock	Other agriculture[a]	Food processing	Mining	Paper, wood	Petro-chemical	Textiles, garments	Heavy manufact.	Light manufact.	Other manufact.[a]	Public services	Other services[a]
Long-run	0.4	0.7	0.2	0.0	1.3	0.7	1.3	2.6	4.0	2.0	0.0	1.6
Consumption												
First	0.4	0.2	−0.4	0.5	0.5	−1.0	0.5	0.4	0.3	0.1	0.8	−0.1
Short-run	0.4	0.6	−0.1	0.6	0.8	−0.9	0.7	0.7	0.5	0.3	−0.3	0.2
Long-run	0.5	1.0	0.1	0.7	1.0	−0.6	0.9	1.1	0.7	0.5	−1.2	0.6

Source: Authors' computation based on simulation results

[a]Constrained industries: investment from constrained firms, by sector

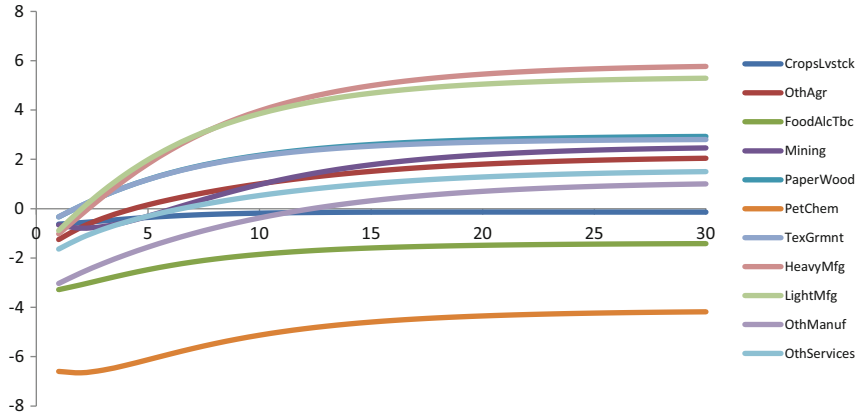

Fig. 10 Effects on exports, by sector (production tax financing) (Source: Authors' computation based on simulation results)

The positive spillover effects of a higher public capital stock improve the competitiveness of domestic producers in the international market. Indeed, exports recover in both the short and the long-run in nearly every sector (See Fig. 10), eventually outpacing relative growth in sectoral imports (See Fig. 11). Food processing and petrochemicals sectors are exceptions in this regard because the Philippines is a net importer of food and oil. Export growth is concentrated in manufacturing sectors (particularly textiles, light manufacturing and heavy manufacturing) which were already export-oriented. Import growth outpaces export growth in the crops/livestock and food/beverage/tobacco sectors throughout the scenario, reflecting the Philippine economy's general dependence on imports in these sectors.

All sectors experience an increase in investment over time (Table 6). As a major producer of capital goods, heavy manufacturing registers the greatest expansion in investment (2.3 % in the first period and 4.9 % in the long-run). This strong investment growth also explains the significant short- and long-run output and export growth in the heavy manufacturing sector, since it directly benefits from the positive supply-side effects of higher public investment. The shadow price of capital immediately rises, and continues to do so in the short run because the increase in public investment crowds out private investment. This price eventually falls in the long-run due to the productivity-enhancing effects of increased public spending on infrastructure.

In summary, the sectoral effects suggest that the productivity-enhancing effects of higher public investment strengthen over time, with the manufacturing and services sectors benefiting relatively more than the agricultural sector in terms of greater output and exports (See Figs. 9 and 10). Compared to scenario 1, the net impact of the tax financing scenario is a reallocation of factors, particularly of labour, from the agricultural sector towards the light manufacturing and heavy manufacturing sectors.

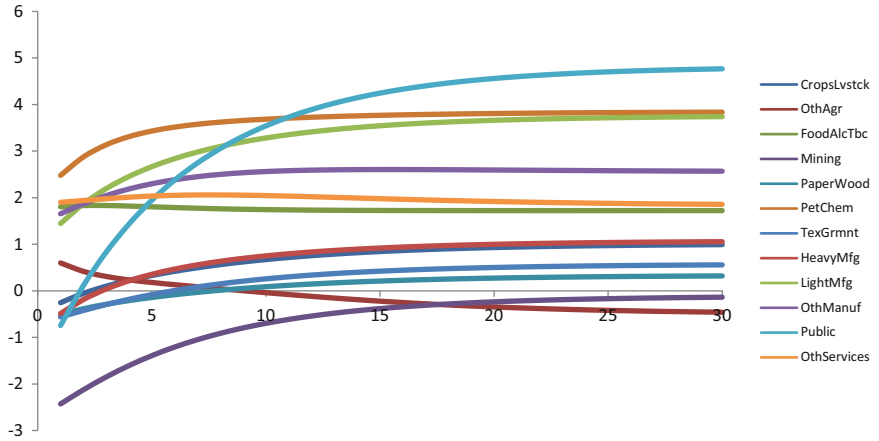

Fig. 11 Effect on imports, by sector (production tax financing) (Source: Authors' computation based on simulation results)

Poverty and Inequality Effects

We now analyze the poverty and distributional effects of higher public investments in the Philippines. As shown in Table 7, the direction of changes in the poverty headcount and Gini inequality coefficient are identical in both financing scenarios, although the magnitude of the impact is greater under the international financing scenario. The poverty headcounts under the foreign and tax financing scenarios respectively rise by 0.74 and 0.62 percentage points in the first year, but fall in the short and long run (respectively −0.63 and −1.64 under foreign financing and −0.21 and −1.07 under tax financing).

These changes in poverty and inequality result from changes in household income and consumer prices. Indeed, a decomposition of the factors behind changes in the poverty headcount into income and price components (Table 7) reveals that, during the first year and under the tax financing scenario, higher consumer prices and lower income (wages and self-employment) both lead to a higher incidence of poverty. In the foreign financing scenario, however, higher wages limit poverty increase in the first year, but not by enough to offset the impact of higher consumer prices, resulting in a higher incidence of poverty.

The poverty headcount falls in both the short and long run. This occurs because the positive supply-side effects of increased public investment accrue over time, leading to higher wages and returns to capital (Fig. 12). Higher factor returns in the short and long run enhance the poverty-reducing effect of income, offsetting the poverty-increasing effect of higher consumer prices. Regardless of the scenario, it is the combined contribution of wage and self-employment income that allows the

Table 7 Poverty and inequality effects (percentage points from baseline)

	International financing			Tax financing		
	First period	Short run	Long run	First period	Short run	Long run
Poverty headcount						
Base (national)	29.0					
Simulation	0.74[a]	−0.63[a]	−1.64[a]	0.62[a]	−0.21[a]	−1.07[a]
Components of changes in poverty headcount[b]						
Growth	0.65	−0.63	−1.73	0.63	−0.24	−1.08
Redistribution	0.09	0.00	0.08	−0.01	0.03	0.02
Change (in % points) in poverty headcount due to change in:						
Wage	−0.18	−0.72	−1.22	0.20	−0.25	−0.83
Self-employment	0.05	−0.39	−0.64	0.16	−0.17	−0.46
Own-consumption	0.00	0.00	0.00	0.00	0.00	0.00
Consumer prices	0.90	0.50	0.23	0.30	0.24	0.14
Residual	−0.03	−0.02	−0.01	−0.04	−0.03	0.08
Poverty headcount (by location)						
Urban	0.38	−0.61	−1.43	0.36	−0.23	−0.95
Rural	1.09	−0.65	−1.86	0.87	−0.20	−1.17
Poverty headcount (by household type)						
Constrained	0.77	−0.55	−1.42	0.55	−0.24	−0.83
Non-constrained	0.73	−0.64	−1.68	0.63	−0.21	−1.10
Gini coefficient						
Base (national)	0.42					
Simulation (change in % points)	0.036	−0.013	−0.004	0.016	−0.003	−0.006

Source: Authors' calculation based on simulation results

Note: Base poverty headcounts are 14.2 (urban), 43.4 (rural), 45.4 (constrained) and 26.7 (non-constrained)

[a]The difference (relative to the base year) is statistically different at the 1 % level

[b]Decomposition based on Shapley value (see Araar and Duclos 2009 for details on using *dfgtgr* command in DASP)

poverty headcount to fall in the medium and long run, although rising wage income is the dominant factor in this regard.

Table 7 also shows the changes in the poverty headcount by location (urban and rural) and household type (constrained and non-constrained). Households in rural areas are more sensitive to the productivity-enhancing effects of public investment, as reflected by higher short- and long-term reductions in poverty headcounts than their urban counterparts. Similarly, higher returns to factor income drive stronger declines in the poverty headcount among non-constrained households than among constrained households, especially in the long run.

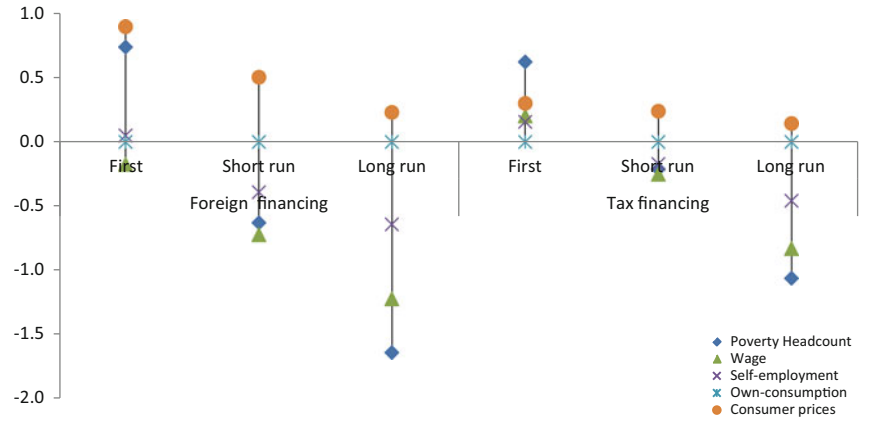

Fig. 12 Contribution to changes in poverty headcount (scenarios 1 and 2, percentage points from baseline) (Source: Authors' calculation based on simulation results)

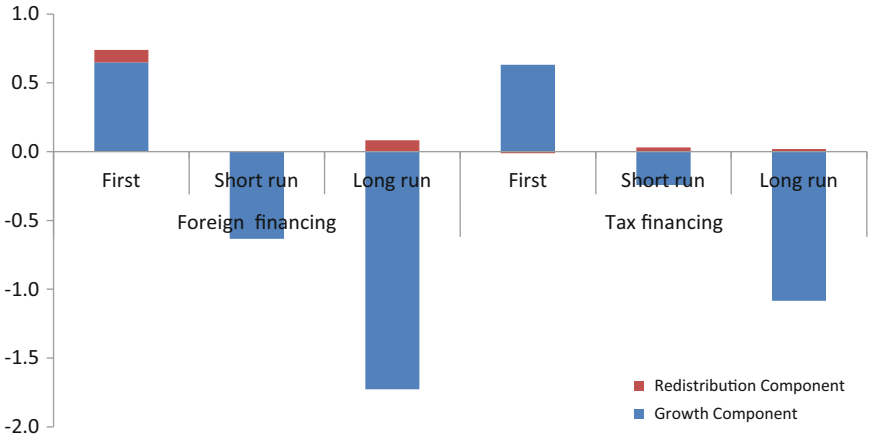

Fig. 13 Growth and redistribution components (changes in poverty headcount, percentage points) (Source: Authors' calculation based on simulation results)

Finally, a decomposition of the factors behind changes in poverty headcounts, into growth and redistribution components (Fig. 13), reveals that, in the long run, the growth component reduces poverty in both the international financing and the tax financing scenarios.

Sensitivity Analyses

In addition to the two policy scenarios analyzed above, we also used the model to simulate alternative assumptions regarding the value of the elasticity of output to public capital. We test the sensitivity of the results to our assumed value for the elasticity of output to public capital (0.15) by recalculating our findings with elasticities of 0.1 and 0.2.

We present these alternative results in Table 8 for selected macroeconomic indicators, the poverty headcount and the Gini coefficient. For the sake of comparison, we present these selected statistics under the original assumption that the elasticity of output to public capital is 0.15. The general trend observed here is that the magnitude of the results increases with the elasticity of output to public capital. We find that real GDP is at least 0.01 percentage points higher in the first year and is no less than 1 percentage point higher in the long run; the long term impact rises with the elasticity of output to public capital.

The results follow the same general trend in terms of changes in poverty and inequality, both in the first year and in the long run. Indeed, the change in the poverty incidence increases as the elasticity of output to public capital increases from 0.1 to 0.2. Note that the long-run impact on inequality is slightly lower when testing values of 0.15 and 0.2 for the elasticity of output to public capital. The sensitivity analyses does, however, confirm that the effects of higher public investment on the economy and on poverty in the Philippines are quantitatively robust to differing assumptions in relation to the elasticity of output to public capital.

Summary and Insights

In the Philippines, public expenditures on physical infrastructure (particularly transportation and utility infrastructures) and the level of public educational spending are both comparatively low. The current government has embarked on policies that aim to further promote robust economic growth and eradicate poverty, in line with commitments to meet its MDGs. One of the policies being pushed primarily concerns infrastructure. This paper contributes to the policy debate on the role of public infrastructure in economic growth and poverty reduction in the Philippines. Our preliminary results reveal that the positive supply-side effects of higher public investment expenditure manifest over time through higher capital accumulation and related improvements in productivity.

In conclusion, the simulation results suggest that a higher public infrastructure investment-to-GDP ratio not only brings about positive real GDP effects, but also reduces poverty and inequality in the short and the long-run. The simulation results follow a generally similar pattern, although the magnitude of the results is greater under the international financing scenario; this is due to the absence of higher

Table 8 Sensitivity of results to changes in elasticity of output to public capital

	Foreign financing						Tax financing					
	Elasticity of output to public capital											
	0.1		0.15		0.2		0.1		0.15		0.2	
	1st year	LR	1st year	LR	1st year	LR	1st year	LR	1st year	LR	1st year	LR
Aggregate results												
Real GDP	0.0	2.0	−0.1	2.9	−0.1	3.9	−0.1	1.0	−0.2	2.0	−0.2	3.0
Wage rate	0.7	4.3	1.0	6.5	1.4	8.9	−1.1	2.1	−1.0	4.1	−0.8	6.4
Total investment	6.1	7.4	6.4	8.2	6.8	9.1	5.0	6.3	5.2	7.1	5.5	8.1
Total consumption	1.5	1.9	2.2	2.7	2.8	3.5	1.5	2.3	1.5	2.3	1.5	2.3
Total exports	−2.2	0.9	−2.8	2.0	−3.3	3.3	−0.7	2.5	−1.2	3.5	−1.8	4.6
Total imports	2.1	2.7	2.6	3.5	3.0	4.3	0.7	1.9	1.0	2.5	1.4	3.3
Real exchange rate	−1.2	−0.4	−1.6	−0.5	−1.9	−0.5	−0.3	−0.4	−0.6	−0.4	−0.9	−0.4
Government revenue	8.1	9.7	8.4	10.9	8.8	12.2	6.6	8.4	6.9	9.6	7.2	10.8
Additional production tax rate (%)	–	–	–	–	–	–	25.8	22.9	27.0	22.4	28.2	21.8
Additional foreign grant (% of GDP)	1.1	1.0	1.1	0.9	1.2	0.9	–	–	–	–	–	–
Poverty and inequality												
Poverty headcount	0.2	−1.2	0.7	−1.6	0.9	−2.6	0.5	−0.4	0.6	−1.1	0.7	−1.8
Gini coefficient	0.0	−0.1	0.0	0.0	0.0	0.0	0.0	−0.1	0.0	0.0	0.0	0.0

Source: Authors' calculation based on simulation results

LR long run

production taxes that slightly hinder the competitiveness of domestic producers. For instance, public infrastructure spending financed by international borrowing at concessional rates of 6 % caused output to expand in all sectors in the long-run, whereas output does not expand in all sectors in the production tax financing scenario. Moreover, the decline in poverty is greater in both the short and long run when increased public infrastructure spending is financed through international borrowing rather than by production taxes. In other words, the selection of a financing scheme for public infrastructure investment matters. The narrow tax base in the country is an important factor that allows our simulation results to confirm that international borrowing is a better alternative to tax financing—i.e., in line with the goal of improving the economy's physical infrastructure to create job opportunities, improve productivity and complement its social protection measures.

Against this backdrop, the Philippine government needs to become more proactive in finding ways to finance increased public investment expenditures. One important policy response is to fast track public-private partnerships (PPPs), to provide financial and technical assistance for infrastructure projects and to increase public education spending. Another is for the government to source additional international financing at concessional rates, or to devise measures to broaden the tax base to finance public investments.

Providing financing for PPP projects in the Philippines is indeed an important issue. The legal and regulatory environment as well as the institutional framework for PPPs has already been established in the country since the 1990s, with PPPs offering nine contractual arrangements—including build-operate-transfer (BOT), build-own-operate (BOO) and build-lease-transfer (BLT) projects, among others. As of August 2012, there were 22 PPPs in the Philippines, including a school infrastructure project (the PSIP); this project aims to build 9,300 public school classrooms for the Philippine government's Department of Education through a BLT at a total cost of US$239 million. The Philippines has been attracting greater foreign and domestic investments amid improving investor confidence and a liquid financial system. In fact, certain financial institutions—particularly banks and insurance companies—have signalled keen interest in providing financial support for the country's PPP programs, including the PSIP.

To encourage greater private sector participation, government guarantees are being provided to cover the risks inherent to PPP projects. However, if not properly priced and managed, these guarantees create contingent liabilities that could potentially worsen the government's fiscal risks. The Philippine government thus needs to adopt a better framework for granting guarantees: it should include a more accurate pricing mechanism—such as a guarantee fee that fully takes into account the different risks of the project and market conditions—in order to ensure a more efficient allocation of government resources (Llanto 2007). A potential area for future research is to simulate the macroeconomic, sectoral, poverty and income distribution impacts of public infrastructure spending in each key infrastructure sector in the Philippines: education, power, telecommunications, transportation and water. Such an initiative would help policymakers in the country as well as donor

agencies better allocate their resources to fund the development of each infrastructure sector, thereby promoting inclusive growth and alleviating poverty and income inequality.

Acknowledgements PEP is financed by the Department for International Development (DFID) of the United Kingdom (or UK Aid) and the Government of Canada through the International Development Research Center (IDRC). This particular program of research received separate funding from the Australian Agency for International Development (AusAID). We thank participants in several PEP general meetings, the 2013 GTAP annual conference in Beijing and the 2013 GDN annual conference in Manila for helpful comments. We also salute the support and advice provided by governmental and non-governmental counterparts. In particular, the authors are grateful to John Cockburn, Yazid Dissou, Jean-Yves Duclos and Luca Tiberti for technical support and guidance, as well as Tomas Africa and Randy Spence for valuable comments and suggestions.

Appendix 1: Figures

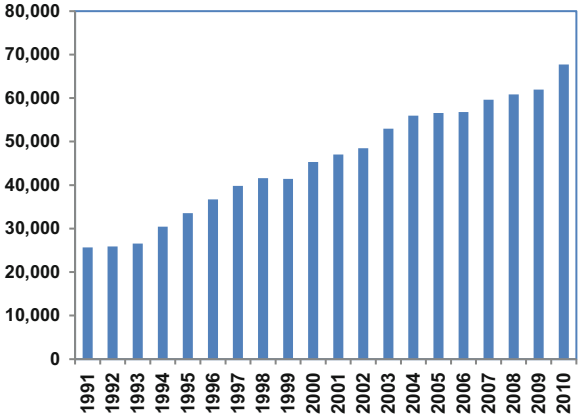

Fig. 14 Power generation/consumption in the Philippines, 1991–2010 (gigawatt-hours) (Source of basic data: Department of Energy, Republic of the Philippines)

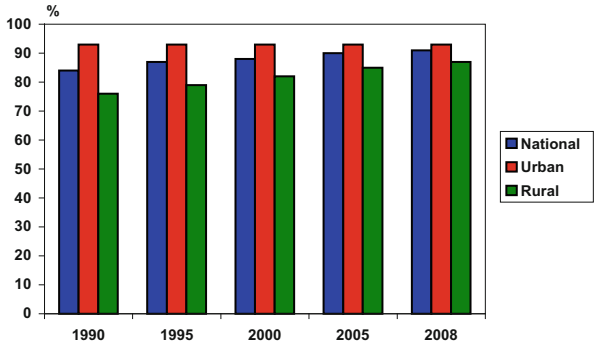

Fig. 15 Proportion of population with access to improved water source in the Philippines: 1990, 1995, 2000, 2005, 2008 (Source of basic data: The World Bank's World Development Indicators Database)

Appendix 2: Tables

Table 9 Poverty incidence for selected subpopulation characteristics based on 2006 Philippine FIES

Variable	Estimate	Standard Error	Variable	Estimate	Standard Error
Type of household			**Class of worker (household head)**		
Single household	0.277	0.003	Worked for private Establishment	0.257	0.004
Extended household	0.249	0.004	Work for the government	0.194	0.008
			Self-employed without any employee	0.347	0.004
			Employer in own family-operated	0.237	0.008
Headship			Worked with pay in own family-op	0.173	0.051
Male headed	0.286	0.002	Worked without pay in own family	0.165	0.026
Female headed	0.202	0.005			
Marital status of household head			**Number of members Employed**		
Single	0.171	0.010	1	0.284	0.004
Married	0.283	0.003	2	0.267	0.004
Widowed	0.233	0.006	3	0.259	0.007
Divorced/ separated	0.199	0.014	4	0.273	0.011
Unknown	0.463	0.250	5	0.297	0.020
Job status of the household head			6	0.306	0.041
with job/business	0.182	0.005	7	0.273	0.77
no job/business	0.287	0.002	8	0.161	0.107

Source: Authors' computations using FIES

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Growth and Distributive Effects of Public Infrastructure Investments in China

Yumei Zhang, Xinxin Wang, and Kevin Chen

Introduction

China has recently been spending more than 10 % of total annual government expenditures on public infrastructure. In late 2008, when the global financial crisis occurred, a four trillion yuan package was put into action to stimulate domestic economic growth. Public infrastructure investment in 2009 and 2010 was respectively 60 % and 80 % higher than in 2008. China has managed to sustain rapid economic growth in recent years. However, disparities between rich and poor have risen, and China has become one of the most unequal countries in the world. Despite high overall economic growth rates, the Chinese government is becoming increasingly concerned about high and rising income inequality. Reducing poverty and inequality through inclusive growth has become a major mandate of development policy. President Hu Jintao formally endorsed inclusive growth as a national development strategy at the Asia-Pacific Economic Cooperation (APEC) in November, 2009.

Adequate infrastructure is critical for ensuring the effective functioning of the economy. Well-developed infrastructure can reduce the effect of distance between regions, integrate the national market and connect it to markets in other countries and regions at a low cost. China's 12th Five-Year Plan (2011–2015) emphasizes the need to "establish the sustainable basic public service system, and improve the ability to safeguard and promote equal access to basic public services," to "strengthen rural infrastructure and public services" and to "improve the quality and efficiency of

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J. Cockburn et al. (eds.), *Infrastructure and Economic Growth in Asia*,
Economic Studies in Inequality, Social Exclusion and Well-Being,
DOI 10.1007/978-3-319-03137-8_4,

investment." The Premier of China, Wen Jiabao, in January of 2012 referred to the need to "continuously improve basic infrastructure in rural areas" in his latest speech "The path of Chinese agriculture and rural development," where he promoted the role of public finance through construction of public infrastructure to improve people's social welfare. The quality and reach of infrastructure networks are believed to not only impact economic growth but also to help reduce income inequality and poverty in a variety of ways (WEF 2011). In other words, public infrastructure investment (PII) can be viewed as an inclusive growth strategy.

Most existing studies on PII have focused on its impacts on economic growth (such as Ma et al. 2001; Liu 2003; Demurger 2001). Only a handful of academic studies have looked at the distributive effect of PII. Fan et al. (2002) and Gao and Li (2006) analyzed the poverty reducing effects of infrastructure in rural China. Zhang and Wan (2004) identified the specific role of rural infrastructure, shedding new light on how to allocate limited public resources to promote both growth and regional equity. The main methods used to analyze the impacts of public infrastructure are econometric tools and a computable general equilibrium (CGE) model.

This chapter assesses both the growth and distributive effects of PII in China using an integrated intertemporal dynamic model and a microsimulation model – it is useful to note that the analysis presented in this chapter is the first application of such an integrated CGE and microsimulation model to the case of China.

We employ an intertemporal dynamic general equilibrium model with public infrastructure capital and heterogeneous consumers and firms (constrained and non-constrained) as done by Dissou and Didic (2011). The Chinese inter-temporal CGE model is used to analyze the macro effects of the increase in PII. Under a top-down fashion and following the methodology presented in Cockburn et al. (2011), the changes predicted by the macroeconomic model are transmitted to the microsimulation module to simulate the poverty and distributive effects generated by the PII. Two policy scenarios are constructed to compare the effects of different PII financing mechanisms.

The paper is organized as follows: the section "Country Context and Infrastructure Status" introduces the country context and PII in China, then the section "Theoretical Frameworks, Data and Parameters" provides a quick overview of the theoretical models, discusses the data and the parameters, and presents the simulation scenarios. The results are discussed in the section "Discussion of Results", and conclusions and policy implications are summarized in the final section.

Country Context and Infrastructure Status

China Context

China has experienced unprecedented economic growth, with average annual growth of 10 % since 1978 (Fig. 1). In 2010, the GDP of China was about 40.12 trillion yuan (about $5.9 trillion), ranking China as the 2nd largest economy in the world after the

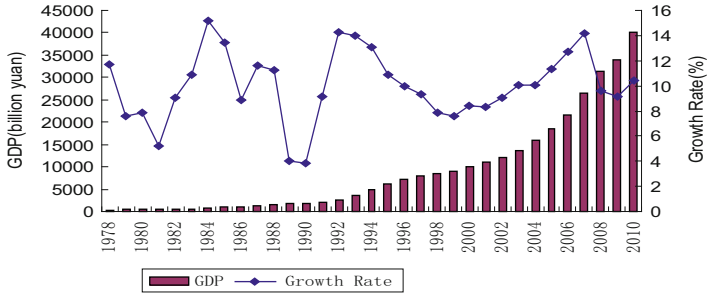

Fig. 1 GDP and real GDP growth in China, 1978–2010 (Source: China Statistical Yearbook 2011)

United States (WEF 2011). China has also become the second largest trading country in the world, with the total value of imports and exports totaling $2.97 trillion, or 143 times more than in 1978, for an average annual growth rate of 16.8 %.[1]

This rapid economic growth supported swift gains in household income, and living standards improved significantly. For example, urban and rural households respectively had incomes of 19,109 yuan and 5,919 yuan in 2010, nearly ten times their levels in 1978. The annual average real growth rate of per capita income for both urban and rural households was over 7 %. The share of the household budget spent on food consumption decreased from 57.5 % in 1978 to 35.7 % in 2010 in urban areas, while the corresponding decline was from 67.7 % in 1978 to 41.1 % in 2010 among rural households. Meanwhile, China has achieved tremendous success in poverty reduction over the past three decades. The official poverty lines show an incidence of poverty that declines from 33 % in 1978 to 2.8 % in 2010. China has the largest population in the world (1.34 billion in 2010), but is ranked just 121st of 215 countries in terms of per capita gross national income (GNI) (NBS 2011). China still has the second largest number of poor people in the world, after India, with about 129.6 million undernourished people in 2004–2006 (FAO 2011). What is more disturbing is that China's economic growth has been accompanied by rising inequality. The gaps between rural and urban areas and between the western and eastern regions of China have increased under rapid economic growth. For instance, the urban to rural household income ratio increased from 2.6 times higher in 1978 to 3.2 times higher in 2010. The Gini coefficient reached 0.47 in China in 2009 (World Bank 2009), well exceeding the "international alerting line" of 0.4. China has become one of the most unequal countries in the world.

Infrastructure Status

China's infrastructure has improved significantly over the past three decades. This includes progress towards increasing public spending on infrastructure at a level

[1] http://www.gov.cn/zwgk/2011-12/07/content_2013475.htm

Table 1 Length of transportation routes (1,000 km)

Year	Railways in operation	Highways	Navigable inland waterways	Total commercial air routes	Petroleum and gas pipelines
1978	51.7	890.2	136.0	148.9	8.3
1990	57.9	1,028.3	109.2	506.8	15.9
2000	68.7	1,402.7	119.3	1,502.9	24.7
2010	91.2	4,008.2	124.2	2,765.1	78.5

Source: China Statistical Yearbook (2011)

that is more in line with China's development needs (OECD 2006). China overall competiveness index ranked 26th among 142 economies and the competitiveness index of infrastructure ranked 44th (WEF 2011).

Transportation

China's transportation system has improved greatly with increased public investment in transportation infrastructure. In 2010, a total of 91.2 thousand km of railway were in operation, or 1.76 times that in 1978. The highway is the fastest growing line of transportation, with a length of 4 million kilometers in 2010, or more than 4.5 times that of 1978. Commercial (civil) aviation routes have also improved substantially over this period of time, with a total length of 18.6 times further in 2010 than in 1978. This major increase in railways, highways and commercial aviation may have reduced the relative significance of the navigable inland waterways, which has hardly changed in the past 30 years (Table 1).

Electricity

In 2010, total electricity output was about 3,703 Twh in China. To improve the living standard of rural households, the Chinese government now pays more attention to public infrastructure in rural areas. Irrigated land area totalled 60.35 million hectares in 2010, or 34.2 % more than in 1978. Hydropower stations in rural areas numbered 44,815 in 2010, and had a generating capacity of 59.24 Gwh, or 26 times that of 1978. The total amount of electric power generated in rural area was 204.4 Twh in 2010 (Table 2).

Postal and Telecommunication Services

In 2010, each post office served an average of about 18,000 people, and nearly 98.96 % of administrative villages had a post office. Telephones (including mobile telephones) numbered about 86.41 sets per 100 persons. Broadband internet access was available in 80.11 % of administrative villages (NBS 2011). The data shows great improvements of postal and telecommunication services in China (Table 3).

Table 2 Irrigation, hydropower stations and power generation in rural China

Year	Irrigated area (millions hectares)	Hydropower stations		Kwh of electric power generation (Twh)
		Number	Generating capacity (Gw)	
1978	44.9650	82,387	2.284	
1990	47.4031	52,387	4.288	418.1
2000	53.8203	29,962	6.985	875.5
2005	55.0293	26,726	10.992	1,357.2
2006	55.7505	27,493	12.430	1,483.6
2007	56.5183	27,664	13.666	1,634.6
2008	58.4717	44,433	51.274	1,627.6
2009	59.2614	44,804	55.121	1,567.2
2010	60.3477	44,815	59.240	2,044.4

Source: China Statistical Yearbook (2011)

Table 3 Level of postal and telecommunication services (2005–2010)

Item	2005	2006	2007	2008	2009	2010
Number of post offices	65,917	62,799	70,655	69,146	65,672	75,739
Length of postal routes and rural delivery routes (millions km)	6.9715	6.9364	7.1705	7.3500	7.704	8.326
Percentage of administrative villages with post office (%)	98.96	99.40	98.40	98.50	98.80	98.96
Telephones (including mobiles), /100 persons	57.22	63.40	69.45	74.29	79.89	86.41

Data sources: China Statistical Yearbook (2011)

Public Infrastructure Investment

As data on PII is not readily available, researchers must rely on data from different sources. OECD (2006) used total fixed asset investment to analyze the main components of government capital spending including transportation, agriculture and education. Liu (2009) used the state's budgeted investment in fixed assets as the public infrastructure investment. Song (2011) chose infrastructure investments in just two sectors: (1) transportation, storage, postal and telecommunication services; and (2) production and supply of electricity, gas and water. In this study, we take the state's budget investment in fixed assets as a measure of PII. Sources of funds for investment in fixed assets are categorized as funds from the state budget, domestic loans, foreign investment, self-raised funds and others.

In China, public infrastructure investment increased very quickly, especially after 1997, the year of the Asian financial crisis. At that time, the government increased fiscal expenditures on public infrastructure to stimulate domestic demand and to promote economic growth. PII increased from 69.7 billion yuan in 1997 to 1,467.8 billion yuan in 2010, for an average annual growth of real PII of 24.55 % over 1997–2010. The same reasoning was also behind increased public investment in response to the 2008 global financial crisis. The Chinese government formulated a stimulus package that injected 4 trillion yuan to stimulate the economy. Public

Table 4 Public expenditures on infrastructure in China, 1997–2010

Year	Public infrastructure expenditures (PII, billions yuan)		PII as share of total government expenditures (%)	PII/GDP (%)
	Current price	2005 constant price		
1997	69.7	73.2	7.5	0.9
1998	119.7	126.7	11.1	1.4
1999	185.2	198.8	14	2.1
2000	211.0	225.5	13.3	2.1
2005	415.4	415.4	12.2	2.2
2006	467.2	460.3	11.6	2.2
2007	585.7	550.6	11.8	2.2
2008	795.5	706.1	12.7	2.5
2009	1,268.6	1,134.1	16.6	3.7
2010	1,467.8	1,270.3	16.3	3.7

Source: China Statistical Yearbook (2011)

infrastructure investment was 60 % higher in 2009 than in 2008. PII as a share of total government expenditures also increased from 7.5 % in 1997 to 16.6 % in 2009. The PII-to-GDP ratio was also higher, at 3.7 % in 2009 and 2010 (Table 4).

Theoretical Frameworks, Data and Parameters

Overview of the Theoretical Models

This paper applies a macro–micro simulation methodology in the context of a computable general equilibrium (CGE) model to analyze the impacts of an increase in public infrastructure investment. CGE models are able to capture the complex direct and indirect interactions between public infrastructure investment, factor markets, commodity markets, households, the government, private firms and foreign markets. However, CGE models cannot fully capture the heterogeneous impact on Chinese individuals and households and, in particular, are not able to take into account the inequality within each group. On the contrary, the microeconomic component can capture the full heterogeneity of economic agents by modelling different individual and household behaviors based on household survey data. Specifically, the effects of the increase in public infrastructure investment on households' welfare are captured through changes in wage and non-wage revenues, commodity prices and savings. A combination of the macro and micro components is needed to capture the impacts of the additional public infrastructure investment on households and to identify whether the increased public infrastructure investment affects all households across the country in the same manner. The CGE model and the micro-econometric behavioral model are linked in a "top-down" fashion to assess the various impacts of public infrastructure on households. We will now summarize the theoretical models and elaborate on some issues which are specific

to the case of China. The macro- and micro-simulation models are presented in chapter "The Growth and Distributive Impacts of Public Infrastructure Investments in the Philippines". For interested readers, the complete specifications of the CGE model can be found in Dissou and Didic (2011) while the full description of the microsimulation model is in Cockburn et al. (2011).

CGE Database: SAM and Parameters

The dataset used to calibrate the dynamic CGE model to the benchmark equilibrium is the Social Accounting Matrix (SAM). The SAM is built using the 2007 input–output (IO) table from the China National Bureau of Statistics. To solve the model conveniently, we aggregate the 42 sectors from the IO table into 17 sectors. The data in the SAM are mainly from the China Statistical Yearbook (2010) and China Financial Yearbook (2008).

The sectoral structure of the Chinese economy, based on the 2007 SAM, is presented in Table 5. The sectors with the largest value added are other services, agriculture, and machinery and equipment. Household consumption is much more targeted toward agriculture, food processing, retail and catering, and other services than toward other sectors. Construction is the sector with the highest total investment, with more than half (55.81 %) of total investments being allocated to this sector. Machinery and equipment comes second at 33.67 % of total investment. Machinery and equipment is the largest export and import sector. The textiles sector is also fairly export-oriented, with 14.54 % of its production being exported. The mining sector is fairly dependent on imports, and takes in 13.97 % of imports.

Most of the parameters can be calculated directly from the SAM, while the remaining elasticity parameters are obtained from the literature. The elasticity of substitution of CES production, and of the Armington function and CET functions, are obtained from Zhai and Hertel (2005). All the parameters used in the CGE model are presented in the appendix (Table A1). As in most studies, the adjustment cost parameter in the installation cost function is set to 2. The effects of long-run population growth are adjusted to 2.5 % to account for growth of the population (0.5 %) and labour productivity (2.0 %).

The model accounts for the capital stock in the production function, but capital is not observed directly in many sectors. This leads us to use the growth rate approach to derive the capital stock in each sector with investment data from the China Statistical Yearbook. We then adjust the data on the basis of the capital stock study by Wu (2009), who estimated the stocks of capital in agriculture, manufacturing and services.

Public capital output elasticities are estimated to range anywhere from 0.06 to 0.59 across countries (Ratner 1983; Munnell 1990; Argimon et al. 1994; Otto and Voss 1994; Ramirez 2002). We choose the output elasticity of public capital as estimated in Song (2011), who uses a three-step non-stationary panel analytical procedure and obtains a moderate value of 0.15 for China. This estimate is used for

Table 5 Sectoral structure of Chinese economy based on 2007 China SAM (%)

Sectors	Value added	Household consumption	Government consumption	Total investment	Exports	Imports
Agriculture	10.77	11.55	0.97	1.01	0.70	3.15
Mining	5.19	0.15	0.00	0.00	0.67	13.97
Food processing	3.83	17.28	0.00	0.00	2.00	2.14
Textile	3.36	6.33	0.00	0.00	14.54	1.93
Other manufacture	4.23	2.40	0.00	1.86	6.31	3.69
Electric power, heat power and water	3.52	2.77	0.00	0.00	0.07	0.02
Coking, gas, petroleum	1.49	1.11	0.00	0.00	0.80	1.96
Chemical industry	4.73	2.43	0.00	0.00	7.58	12.30
Nonmetallic mineral products	2.35	0.29	0.00	0.00	1.55	0.51
Metals, metal products	5.87	0.43	0.00	0.90	9.12	6.63
Machinery and equipment	10.53	6.80	0.00	33.67	42.35	45.54
Construction	5.46	0.97	0.00	55.81	0.43	0.30
Transport	7.89	5.58	4.61	1.42	4.69	2.03
Retail and catering services	8.61	13.98	0.00	1.79	4.97	0.71
Real estate	6.06	9.10	1.62	3.23	3.36	3.26
Finance	5.05	4.29	0.77	0.00	0.09	0.17
Other services	11.06	14.53	92.03	0.30	0.78	1.70

Data sources: Calculated from input–output tables of China (2007)

all 17 sectors because we do not have sector-specific elasticities. Sensitivity analysis was performed on the chosen elasticity to assess the robustness of the results.

Household Data

The household survey data was produced by the Chinese Household Income Project (CHIP) of Inter-University Consortium for Political and Social Research. Although a 2007 survey was also carried out, only the 2002 dataset was made publicly available. The 2002 CHIP data was collected through a series of questionnaire-based interviews conducted in rural and urban areas towards the end of 2002, and covered three types of households: urban, rural and migrant. There are a total of 6,835 urban households, 9,200 rural households and 2,000 migrant households included in the survey. The total number of individuals covered by the sample is 37,969. The microsimulations are done on each of these different groups. Sample weights are calculated according to the share of the urban, rural and migrant populations in the total population.

Understandably, it is less than desirable to use 2002 data to estimate the current situation of poverty and inequality in China. In order to capture the recent situation,

we update household consumption expenditures to 2009 using aggregate national household survey data available from the China Statistical Yearbooks. The mean growth rates between 2002 and 2009 for each consumption expenditure category of rural and urban households are calculated by income quintile. The same growth rates are then assumed to hold for the consumption expenditure item in that quintile of rural or urban households. The itemized consumption expenditures of migrant households are updated using information that can be compared to urban households.

Coherently with the CGE model, we divide households into constrained and non-constrained according to their ability to borrow or lend. If the household can participate in public or private credit markets, then the household is assumed to have the ability to smooth consumption and is considered as non-constrained, otherwise the household is constrained. We estimate the probability of being a constrained or non-constrained household using household survey data conducted by CHIP. From the survey data we use, we find that about 75 % of households are constrained and the remainder are non-constrained. The results are largely in line with Zhang and Wan (2004), who estimated that 70 % of households were constrained in 1984–1998 CHIP data.

Finally, before estimating the poverty headcount index, the poverty line must be chosen. The official Chinese poverty line for rural households was 1,196 Yuan per year in 2009. According to this definition, there were about 35.97 million poor people, for a poverty incidence of around 3.6 % in rural China. The Chinese official poverty line is too low and poverty is grossly underestimated. For comparison, the World Bank poverty line of $1.25 per day, or about 2,085 PPP Yuan per year in 2009 is used too.

Since the poverty lines for urban and migrant households are not published by the Chinese government, the difference in living costs between rural and urban areas is used to set the poverty lines for urban and migrant households. According to the World Bank (2009), the living cost in urban areas was estimated at about 1.5 times that of rural areas. The poverty line for urban and migrant households is thus set at 1.5 times that used for rural areas.

As seen above, the official Chinese poverty line yields a national poverty headcount index of about 3 % and most of the poor are located in rural areas. When the international poverty line is used, the poverty headcount index rises to 28.51 % for rural households, 2.36 % for migrant households and 6.60 % for urban households. However, despite the large difference in the results for each of the two poverty lines, we found fairly consistent poverty trends under the different poverty lines. Given that China increased its poverty line substantially in 2011 to 2,300 Yuan per year, we opt to estimate poverty with the international poverty line.

Simulation Scenarios

We first analyze the broader economic impacts of increased public infrastructure investment under different financing mechanisms. We then simulate the impacts of

higher public infrastructure investment on households' consumption, poverty and inequality.

As public infrastructure investment in China increased rapidly during the last decade, we consider the case of a 20 % increase in the public infrastructure investment-to-GDP ratio. Fixed government savings provides the macro closure. In the first scenario, we assume that the increase in public infrastructure investment is financed by foreign borrowing and, in the second, we assume that the increase is financed by higher production taxes. In the second scenario, a uniform percentage increase in production taxes was imposed proportionately on all constrained and non-constrained firms. This means that, in the second scenario, the initial increase in public infrastructure investment is entirely financed by an increase in the production tax rate.

In the microsimulation, the macro impacts of the two simulations are generated from the CGE model. The changes in the poverty headcount index and Gini coefficients are calculated under both simulations across different timeframes.

We quantify the aggregate and sectoral effects of variables over time as percentage changes with respect to their baseline values and report these effects for the following periods: the first period (the first year following the shock), the short-run (the 5th year), the intermediate run (20th year), and the very long-run (the 100th year). The values obtained in the 100th year denote the steady-state values of the model.

Discussion of Results

Macroeconomic Effects

Simulation 1: Increase in Public Infrastructure Investment Under Foreign Financing

Aggregate effects: The macroeconomic results are shown in Table 6. In the first period, government investment increases by 19.8 % and the public infrastructure-to-GDP ratio increases by 20 %. Foreign borrowing as a share of GDP increases by 0.69 % to balance the government's account. Public infrastructure investment in the first period adds to the level of public capital stock only in the next period.

The increase in public infrastructure investments drives demand for labour and capital, raising the wages and the rental rate capital goods, respectively by 0.41 % and 0.51 % in the first period. Both the constrained and non-constrained households increase their consumption owing to higher labour and capital income. However, in contrast to constrained households, the non-constrained households in anticipation of higher future productivity and capital returns increase their investment in private capital by about 2 % in the first period.

In the immediate period, firms face higher labour and capital costs due to rising wage rates and prices for capital goods. The increased input costs are passed onto

Table 6 Macro-simulation results under scenario 1 and 2 (% deviations from baseline)

	Variables periods					
	Foreign financing			Production tax financing		
Scenarios	First period	Short run	Long run	First period	Short run	Long run
Real GDP	−0.01	0.57	3.86	−0.06	0.03	4.32
Consumption price index	0.39	0.40	0.14	0.08	0.10	0.27
Wage rate	0.41	1.18	4.81	−0.51	0.07	5.74
Rental rate of capital, constrained household/firm	0.18	0.80	0.07	−0.47	0.08	0.13
Price of capital good	0.51	0.38	−0.09	0.20	0.17	−0.03
Real exchange rate	−0.40	−0.36	0.03	−0.12	−0.12	−0.06
Government revenues	2.32	2.45	2.84	1.98	2.07	3.08
Total aggregate consumption	0.61	0.99	3.25	0.46	0.69	3.78
Total consumption of non-constrained households	2.22	2.21	2.47	2.84	2.82	2.65
Total consumption of constrained household	0.31	0.86	3.72	−0.47	−0.12	4.54
Total investment	1.92	2.86	5.68	0.67	1.64	6.71
Government investment	19.84	20.70	24.89	19.79	20.38	25.56
Total private investment	0.97	1.92	4.67	−0.34	0.65	5.72
Non-constrained firms	2.17	3.39	5.56	0.01	1.61	6.90
Constrained firms	−0.21	0.48	3.81	−0.68	−0.29	4.56
Total aggregate capital stock	0.00	0.57	5.59	0.00	0.27	6.43
Public capital	0.00	5.29	24.81	0.00	5.25	25.31
Total private capital stock	0.00	0.32	4.57	0.00	0.01	5.43
Non-constrained firms	0.00	0.64	5.41	0.00	0.17	6.47
Constrained firms	0.00	0.02	3.75	0.00	−0.14	4.44
Total exports	−1.91	−1.13	4.59	−1.13	−0.72	4.95
Total imports	1.16	1.81	4.38	0.37	0.95	5.18
Disposable income, constrained households	0.31	0.86	3.72	−0.47	−0.12	4.54
Labour income, constrained households	0.41	1.18	4.81	−0.51	0.07	5.74
Capital income, constrained households	0.18	0.82	3.82	−0.47	−0.07	4.57
Saving, constrained households	0.31	0.86	3.72	−0.47	−0.12	4.54
Additional foreign borrowing (% of GDP)	0.69	0.63	−0.28			
Increase in production tax rate (%)				3.67	4.01	−2.25

Source: Model results

consumers, driving up domestic prices. In international markets, imported commodities become cheaper due to a 0.40 % increase in the real exchange rate. Imports increase by 1 %, not only due to the higher real exchange rate, but also due to the increase in demand induced by higher public investment. Exports drop 2 % due to higher domestic prices and the higher real exchange rate. Weak Dutch Disease effects are thus observed in the Chinese economy in the immediate period

following increased public infrastructure investment financed by foreign borrowing. Real GDP falls by 0.01 % in the first period.

In the short and the long-run, increased public investment leads to an accumulation of the public capital stock and ongoing improvements in the productivity of labour and private capital. The public capital stock respectively increases by 5.29 % and 24.81 % in the short and the long-run. The stock of private capital also increases by 0.32 % in the short-run and 4.58 % in the long-run. Wages in the short and the long-run respectively rise by 1.18 % and 4.80 % due to improved productivity.

The disposable income of constrained households rises, as do wages, respectively leading to short and long-run increases of 0.86 % and 3.70 %. The consumption of non-constrained households becomes relatively higher (about 2 %) over the course of the simulation because they are able to smooth their consumption. Their total short and long run consumption respectively increase by 0.99 % and 3.25 %.

Public investment also stimulates private investment via improved productivity. Both constrained and non-constrained firms increase their investments in the short and the long-run. Investment by constrained firms rises by 0.48 % in the short-run and 3.80 % in the long-run, while that of non-constrained firms rises even more: 3.39 % in the short-run and 5.63 % in the long-run. Total private investment rises by 1.92 % in the short-run and 4.70 % in the long-run.

In the international market, Dutch disease effects persist in the short-run due to lower exports and higher imports. However, these effects soften gradually and are completely eliminated in the long-run. Lower production costs and increased output improve the international competitiveness of domestic producers over time. At the same time, real exchange rate appreciation slows and becomes negative (0.03 % lower in the long run). It is interesting to note that exports and imports both increase in the long-run, respectively by 4.59 % and 4.38 %.

Despite limited Dutch disease effects observed in the first period and in the short-run due to the continuous inflow of foreign finance, public infrastructure investments play a critical role in enhancing productivity and in stimulating consumption and investment over time. Real GDP is as much as 0.57 % and 3.86 % higher, respectively in the short and the long-run (see Fig. 2). In the long-run, the effects of increased public investment are substantial. The increase in public investment improves productivity and bolsters private investment. The long-run level of investment in constrained and non-constrained firms is respectively 3.81 % and 5.56 % higher than in the baseline. Both constrained and non-constrained households increase their consumption in the long-run, respectively by 3.72 % and 2.47 %. Finally, GDP is as much as 3.86 % higher relative to the baseline scenario.

Sectoral Effects: Public infrastructure investment generates an externality on firm technology and all sectors benefit equally from the increase in public infrastructure investment. There are also some sector-specific effects, especially in the first period and in the short-run.

In the first period, on the demand side, household income increases via rising wages and rents from capital goods. Their rising income allows consumption to increase across all sectors. Dutch disease effects resulting from increased inflows of

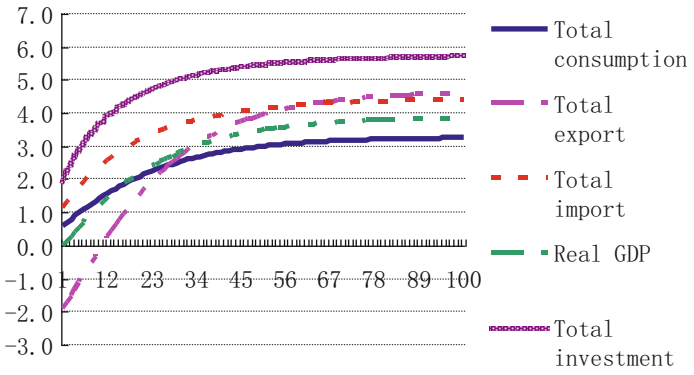

Fig. 2 GDP: demand side effects (international financing) (Source: Model results)

foreign finance cause real exchange rate appreciation, causing imports to rise in all sectors, while exports decline across all sectors. The export-oriented sectors lose their competitiveness in the international market. For example, textiles exports decline immediately by 4.06 %. There are also some shocks to the machinery and equipment sector, which is the largest sector for both imports and exports. Imports in the sector rise by 1.49 % and its exports decline by 1.76 %.

On the supply side, both constrained and non-constrained firms increase their investment in the first period. Non-constrained firms reallocate their investments among sectors according to their rates of return. The nonmetallic mineral products sector attracts more private investment, for a 5.74 % increase, while private investment in the chemical industry sector falls by 0.42 %. The same is observed for labour demand, where rising wages cause some workers to shift between sectors. For example, the textile sector's effective labour demand shrinks 2.49 % due to a decline in its international competitiveness. The construction sector's labour demand increases by 3.08 %. There are also differing changes in the demand for intermediate goods. For example, the intermediate demand for nonmetallic mineral products rises by 1.23 %, while the intermediate use of textiles declines by 1.71 %.

As a result, a number of sectors gain from the increase in public investment under the foreign financing mechanism, but other sectors lose in the first period. Output in the construction sector increases most, by 1.81 %, followed by nonmetallic mineral products, with a 1.05 % increase in sectoral output. Declining sectoral production of 2.22 %, 0.55 % and 0.49 % was respectively recorded in the textiles, chemical industry, and machinery and equipment sectors. Any output changes in other sectors are smaller than those mentioned in the first period.

In the short and the long-run, sectoral productivity increases due to higher public investment and public capital. The negative effects on certain sectors gradually dissipate, and positive effects become increasingly more important over time. As a result, all sectors gain from increased public investment in the long-run. Total production in several sectors is boosted by more than 5 % as a result of the policy:

metal and metal product manufacturing (+5.71 %), nonmetallic mineral product manufacturing (+5.46 %), machinery and equipment manufacturing (+5.22 %) and real estate (+5.15 %). The textiles sector also gains from increased long-run public investment, with a 0.39 % increase in its sectoral output, which is much less than in other sectors.

Simulation 2: Increase in Public Infrastructure Investment Under Production Tax Financing

In simulation 2, we assume that the increase in public infrastructure investment is financed by a production tax imposed on all firms, instead of foreign borrowing. In this case, the overall effects of increased public investment in infrastructure depends on trade-offs between the positive productivity effects of public infrastructure and the distortionary effects of the increased tax burden. The aggregate effects are presented in the last three columns of Table 7. Certain results are similar to those obtained in the previous simulation, particularly in the long-run. However, there are notable differences between the two simulations in the early periods following increased investment in infrastructure.

Aggregate effects: In the first period, public investment increases by 19.79 % and the production tax rate increases by 3.67 % to balance government payments. The higher tax imposes an additional burden on firms and exerts negative shocks on the economy. Contrary to simulation 1, the wage rate and the capital rental rate of constrained households respectively decline by 0.51 % and 0.47 % in the first period. As a result, the disposable income of constrained households is 0.47 % lower relative to the baseline scenario. This negative effect on income leads constrained households to decrease their first-period consumption by 0.47 % as well. However, the non-constrained households increase their first-period consumption by 2.84 % due to their ability to smooth consumption. Due to decreased consumption of constrained households, total consumption in the first period rises by less than in the previous simulation.

Public investment appears to crowd out private investment in the first period. Total private investment falls by 0.34 %. This crowding out effect stems from the increase in the price of capital goods (which increases by 0.2 %) and a reduction in the income of constrained households. As a result, constrained firms reduce their investment by 0.68 % in the first period. Due to the increase in both the production tax rate and the price of capital goods, the non-constrained firms barely increase their investment (0.008 %) in the first period. This is very different from the results of simulation 1 where total private investment increases by 0.97 % in the first period.

In the international market, real exchange rates are 0.12 % higher due to the increase in public investment, which stimulates a 0.3 % increase in import demand, while it lowers export demand by 1.13 % in the first period. As a whole, real GDP falls by 0.06 % in the first period - a much steeper decline than registered in scenario

Table 7 Sectoral effects under scenario 1: foreign borrowing financing (% deviations from baseline)

Variables	Period	Agriculture	Mining	Food processing	Textile	Other manufacture	Electric power	Coking, gas and petroleum	Chemical industry	Nonmetallic mineral products	Metals and metal products	Machinery and equipment	Construction	Transport	Trade and catering services	Real estate	Finance	Other services
Gross output	First	−0.06	−0.33	0.13	−2.22	−0.22	−0.03	−0.04	−0.57	1.05	−0.17	−0.49	1.81	0.13	0.18	0.09	0.07	0.20
	Short	0.04	0.52	0.34	−2.43	0.49	0.71	0.72	0.02	2.01	0.84	0.44	2.73	0.90	0.79	0.98	0.72	0.29
	Long	1.50	4.83	2.18	0.39	4.96	4.70	4.60	3.93	5.46	5.71	5.22	5.52	4.58	4.35	5.15	4.13	1.52
Investment	First	0	1.46	0	0	0	0.47	1.85	−0.42	5.74	2.11	1.21	0	0	0	0	0	0
	Short	0	3.46	0	0	0	1.54	3.37	1.74	5.94	3.99	3.49	0	0	0	0	0	0
	Long	0	7.2	0	0	0	3.31	6.57	5.58	7.75	7.54	7.53	0	0	0	0	0	0
Labour demand	First	−0.08	−0.53	−0.01	−2.49	−0.43	−0.28	−0.09	−1.04	1.71	−0.33	−0.80	3.08	0.37	0.01	0.30	0.25	0.11
	Short	−0.05	−0.18	−0.32	−3.16	−0.33	−0.39	0.03	−0.94	1.73	0.10	−0.31	2.78	0.09	0.00	0.08	−0.18	−0.12
	Long	0.92	1.16	−2.58	−3.85	−0.80	−2.49	0.58	−0.36	1.68	1.47	1.47	1.87	−1.31	−1.46	−1.17	−1.98	−1.55
Intermediate use	First	−0.25	−0.03	−0.04	−1.71	−0.07	−0.09	0.00	−0.36	1.23	0.05	−0.23	0.63	0.24	0.01	−0.07	−0.03	0.04
	Short	−0.03	0.80	0.28	−1.73	0.61	0.64	0.73	0.20	2.12	0.98	0.61	1.18	0.92	0.64	0.52	0.63	0.62
	Long	2.30	4.93	2.73	1.32	4.44	4.54	4.51	3.75	5.35	5.42	4.95	3.72	4.35	4.06	3.93	4.18	3.78
Imports	First	1.04	0.73	0.96	0.61	1.20	0.71	0.55	0.46	3.37	1.28	1.49	3.11	1.33	1.05	1.39	1.10	0.83
	Short	2.53	1.49	1.63	1.16	1.73	0.94	1.20	0.89	3.66	1.96	2.21	3.66	1.36	1.42	1.28	0.92	1.26
	Long	9.57	5.13	4.58	3.91	2.67	1.09	4.56	3.16	5.02	4.62	4.64	5.53	2.12	2.38	1.42	1.14	2.69
Exports	First	−1.32	−1.57	−1.43	−4.06	−1.35	−1.02	−1.00	−1.54	−1.34	−1.54	−1.76	−0.70	−1.24	−0.80	−1.32	−1.41	−0.77
	Short	−2.79	−0.61	−2.06	−4.77	−0.50	0.41	−0.07	−0.79	0.29	−0.22	−0.71	0.93	0.38	0.08	0.64	0.44	−1.02
	Long	−7.18	4.47	−2.24	−1.90	6.84	9.78	4.67	4.66	5.93	6.75	5.60	5.50	7.43	6.60	9.38	8.64	−0.14
Consumption	First	0.64	0.75	0.64	0.52	0.65	0.71	0.72	0.75	0.48	0.67	0.68	0.39	0.50	0.61	0.50	0.49	0.64
	Short	0.68	1.16	0.88	0.80	1.07	1.24	1.14	1.17	0.99	1.11	1.09	0.93	1.14	1.08	1.20	1.22	0.93
	Long	1.39	3.31	2.56	2.86	3.78	4.39	3.37	3.48	3.44	3.54	3.42	3.35	4.22	4.06	4.57	4.61	2.88

Note: Constrained industries: Investment by sector of destination for constrained firms following the baseline path

1, where foreign financing of public infrastructure investment led to a 0.01 % decline in real GDP in the first period.

In the short and the long-run, the increase in public infrastructure investment improves the productivity of private capital and labour, and thus increases output. Enhanced productivity brings higher returns to labour and capital. The wage rate increases in the short-run (0.07 %) and in the long-run (5.74 %). Similarly, the capital rental rate of constrained households rises in the short-run (0.07 %) and the long-run (0.132 %).

In the short-run, the positive effects of improved productivity cannot entirely offset the negative effects of the higher production tax rate, and the stock of public capital is only 5.25 % higher than in the baseline. Although the crowding out effects gradually weaken over time, the disposable income of constrained households and investment among constrained firms remain below their baseline values in the short-run.

Continuous increases in public capital stocks exert an increasingly larger positive effect on productivity. The positive effects outpace the negative effects of the production tax in the long-run. Public capital increases by 25.31 % in the long-run and the disposable income of constrained households rises by 4.54 %. The negative effects on the consumption of the constrained households gradually become smaller and eventually become positive due to increased disposable income.

Because the constrained households consume a fixed proportion of their income, their consumptions increase at the same growth rate of income. In the short-run, the growth rate of their consumptions is relatively slow due to the negative impacts from the increased production tax. While the non-constrained households can smooth their consumption, in the short-run their consumption does not change substantially. As a result, we note that the percentage increase in the consumption of constrained households is less than that of non-constrained households in the short-run. In the long run, non-constrained households benefit of the higher investment return due to the increased public investment in infrastructure. Thus, they devote more income for investment, resulting in a growth rate of consumption lower than that of income. In the long-run, the percentage increase in the consumption of constrained households is larger than that of the non-constrained households (4.54 % vs. 2.65 % respectively).

The crowding out effects eventually fade away completely. Constrained and non-constrained firms respectively increase their investments by 4.56 % and 6.89 % in the long-run (see Fig. 3). Both imports and exports rise by about 5 % in the long-run. As a result, real GDP is 0.32 % and 4.32 % in the short and the long-run. Under both financing mechanisms, distortions happen only in the first period and the short-run. Also, as expected, under the foreign financing mechanism distortions are smaller and shorter than under the production tax scheme.

Sectoral Effects: As in scenario 1, sector-specific impacts occur in the first time period, as presented in Table 8. Infrastructure investment financed by the production tax increases the tax burden on firms, reducing their demand for intermediate use in almost all sectors in the first period, except for the construction and nonmetallic mineral product sectors. The following sectors see their use as a production intermediate decline: mining (0.22 %), textiles (0.89 %) and the manufacture of machinery and equipment production (0.36 %).

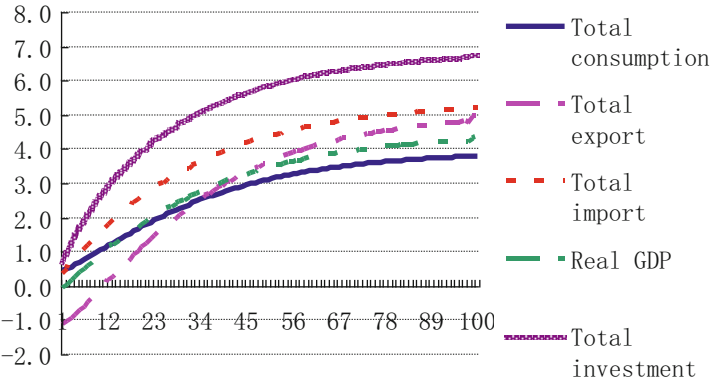

Fig. 3 GDP: demand-side effects (production tax financing) (Source: Model results)

Crowding out effects on private investments are reflected at the sectoral level in the immediate period. The new investments are reallocated among sectors according to sectoral returns to private capital. The level of investment declines in most sectors, except in the nonmetallic mineral product sector, which experiences a 2.08 % increase. This is very different from scenario 1. Investment increases in most sectors in the first scenario, and especially investment in the nonmetallic mineral product sector increases by 5.74 %.

The same is observed for labour demand. The demand for labour in most sectors shrinks in the first period due to a lower marginal product of labour. For example, labour demand in the textiles, electric power and machinery and equipment sectors fall the most, respectively by 1.10 %, 0.80 % and 0.79 %, while positive effects on labour demand are observed in the construction (1.17 %) and nonmetallic mineral product (0.50 %) sectors.

The decline of constrained households' disposable income leads to lower household consumption among these households, while non-constrained households' consumption demand increases slightly (less than 1 %) across all sectors in the first period as a result of having the ability to smooth their consumption. Total domestic demand thus decreases in some sectors and increases in others.

The shocks to international markets are felt most strongly in the textiles sector, with a 2.04 % decline in its exports and a 0.28 % increase in imports in the first period. The shock affects other sectors, such as machinery and equipment, metals and metal products. The agricultural and other services sectors see the opposite effect, with a decrease in imports and an increase in exports.

In the first period, agriculture, food processing, nonmetallic mineral products, construction, transport, real estate, finance and other services see output gains from higher public infrastructure investment, while other sectors register losses. In particular, the output of the construction, other services and manufacturing of nonmetallic mineral product sectors respectively increases by 0.64 %, 0.36 % and 0.26 % in the first period. Meanwhile, production in the textiles and machinery and equipment sectors respectively fall by 1.12 % and 0.54 %.

Table 8 Sectoral effects under scenario 2: production tax financing (% deviations from baseline)

Variables	Period	Agriculture	Mining	Food processing	Textiles	Other manufacture	Electric power	Coking, gas and petroleum	Chemical industry	Nonmetallic mineral products	Metals and metal products	Machinery and equipment	Construction	Transport	Trade and catering services	Real estate	Finance	Other services
Gross output	First	0.17	−0.33	0.1	−1.12	−0.16	−0.14	−0.16	−0.34	0.26	−0.42	−0.54	0.64	0.05	−0.04	0.03	0.01	0.36
	Short	0.2	0.25	0.2	−1.41	0.4	0.36	0.39	0.05	1.1	0.28	0.07	1.57	0.65	0.42	0.71	0.47	0.35
	Long	1.67	5.42	2.56	0.27	5.48	5.33	5.2	4.29	6.36	6.52	5.91	6.51	5.12	4.97	5.76	4.66	1.44
Investment	First		−0.44				−1.12	−0.1	−1.28	2.08	−0.45	−0.84						
	Short		1.59				0.41	1.58	0.52	3.4	1.76	1.48						
	Long		8.76				4.25	8.01	6.75	9.61	9.31	9.21						
Labour demand	First	0.19	−0.48	0.17	−1.11	−0.09	−0.8	−0.18	−0.52	0.5	−0.65	−0.79	1.17	0.26	0.03	0.22	0.11	0.42
	Short	0.17	−0.29	−0.17	−1.81	−0.06	−0.32	−0.1	−0.57	0.83	−0.31	−0.49	1.54	0.11	−0.06	0.1	−0.16	0.15
	Long	1.01	1.36	−2.79	−4.5	−1.01	−2.78	0.73	−0.47	2.16	1.82	1.73	2.4	−1.45	−1.54	−1.28	−2.16	−2.03
Intermediate use	First	−0.1	−0.22	−0.02	−0.89	−0.14	−0.2	−0.13	−0.26	0.35	−0.27	−0.36	0.28	−0.02	−0.1	−0.12	−0.12	−0.04
	Short	0.02	0.37	0.18	−1.01	0.36	0.31	0.41	0.11	1.17	0.41	0.23	0.74	0.51	0.35	0.29	0.34	0.36
	Long	2.59	5.59	3.1	1.3	4.96	5.12	5.07	4.15	6.22	6.17	5.59	4.21	4.94	4.57	4.42	4.7	4.24
Total demand	First	0.11	−0.22	0.15	−0.64	−0.05	−0.14	−0.11	−0.23	0.36	−0.27	−0.05	0.64	0.08	0.07	0.15	0.01	0.13
	Short	0.21	0.37	0.3	−0.7	0.46	0.36	0.44	0.14	1.19	0.44	0.6	1.58	0.58	0.49	0.65	0.46	0.27
	Long	2.25	5.58	2.89	1.71	4.99	5.32	5.19	4.15	6.34	6.32	5.71	6.51	4.74	4.64	4.87	4.62	1.77
Imports	First	−0.75	0.07	0.5	0.28	0.31	−0.63	0.26	0.1	1.39	0.46	0.59	1.1	0.19	0.66	0.54	0.12	−0.05
	Short	0.34	0.69	0.99	0.66	0.64	0.1	0.8	0.41	2.12	1.18	1.31	1.96	0.25	0.89	0.46	−0.01	0.24
	Long	11.57	6.01	5.29	4.54	3.4	1.58	5.17	3.73	6.05	5.36	5.44	6.69	2.89	2.83	1.99	1.72	3.4
Exports	First	1.25	−0.81	−0.66	−2.04	−0.53	0.53	−0.84	−0.76	−0.92	−1.25	−1.28	−0.26	−0.11	−0.82	−0.52	−0.16	0.63
	Short	0.04	−0.27	−1.27	−2.77	0.21	0.72	−0.29	−0.3	0.05	−0.56	−0.74	0.81	1.11	−0.11	0.98	1.16	0.4
	Long	−8.78	4.72	−2.47	−2.5	7.18	10.62	5.25	4.82	6.7	7.64	6.22	6.15	7.71	7.42	10.03	9.09	−0.92

Note: Constrained industries: Investment by destination sector for constrained firms follows the baseline pathway

Most of the adverse impacts of tax-financed public infrastructure investment occur in the first period. In the short and the long-run, the additional public investment accumulates into a larger stock of public capital, generating positive effects on sectoral productivity. This resulting gradual increase in sectoral productivity helps attract additional investment in every sector. In the long-run, this leads to higher production in every sector. For example, the construction, manufacture, and processing of metal and metal products sectors' see a substantial increase in their long-run output of about 6 %. The textiles sector, which contracts the most in the first period, eventually recovers to register a 0.27 % higher production in the long-run relative to the baseline.

Sensitivity Analysis

A sensitivity analysis is conducted to see whether the results of the model are sensitive to the choice of the model's elasticity. The output elasticity of public capital stock is the most important parameter underlying the productivity of public infrastructure investments. The elasticity used in the model (0.15) is tested against a lower (0.1) and higher (0.2) elasticity. Several important results of the sensitivity analysis are presented in Table 9. While the size of the effects differ, similar patterns result from these public capital stock production elasticities. Nonetheless, a higher output elasticity of public capital means stronger policy results. For example, increasing the public capital stock production elasticity from 0.1 to 0.2 raises real GDP from 2.53 to 5.22 % higher (see Table 9).

The production function and trade elasticities are also tested in our study, and the results are robust. The sensitivity results are not presented in full for brevity.

Microsimulation Results

The distributive effects are determined via the microsimulation module. Both the poverty and inequality effects are calculated for the two scenarios: the first is financed by foreign financing and the second is financed by a production tax.

Poverty Effects

The poverty effects are assessed against the base year using the international poverty line of $1.25 per day. The results are presented in Table 10. The two financing mechanisms lead to different results in terms of poverty changes in the first period. For example, the poverty headcount ratio increases under the production tax but it decreases under foreign financing. However, with enhanced productivity due to increased PII, the two financing mechanisms both help reduce poverty

Table 9 Sensitivity of results to changes in public capital to output elasticity

	Foreign financing						Production tax financing					
	Low elasticity		Model result		High elasticity		Low elasticity		Model result		High elasticity	
	First period	Long run	First period	Long run	First year	Long run	First period	Long run	First period	Long run	First period	Long run
Real GDP	0.00	2.53	−0.01	3.86	−0.01	5.22	−0.03	2.62	−0.06	4.32	−0.08	6.01
Wage rate	0.32	3.16	0.41	4.81	0.52	6.54	−0.48	3.28	−0.51	5.74	−0.51	8.24
Total investment	1.60	4.03	1.92	5.68	2.21	7.52	0.50	4.22	0.67	6.71	0.84	9.28
Total consumption	0.39	2.12	0.00	5.59	0.84	4.42	0.08	2.04	0.46	3.78	0.84	5.51
Total exports	−1.50	2.79	−1.91	4.59	−2.31	6.55	−0.64	2.96	−1.13	4.95	−1.61	6.98
Total imports	0.93	3.02	1.16	4.38	1.39	5.84	0.19	3.11	0.36	5.18	0.54	7.29
Real exchange rate	−0.31	−0.01	−0.40	0.03	−0.51	0.06	−0.04	−0.01	−0.12	−0.06	−0.20	−0.14
Government revenue	2.24	2.54	2.32	2.84	2.41	3.20	1.93	2.56	1.97	3.08	2.03	3.68

Source: Model results

Note: Low elasticity scenario refers to decreasing public capital output elasticity to 0.1; high elasticity refers to increasing public capital output elasticity to 0.2

Table 10 Poverty headcount and effects of higher PII on poverty (international line of $1.25/day)

National P0 (wrt base year, %)	24.70							
	Foreign financing				Tax financing			
Period	1st	5th	20th	100th	1st	5th	20th	100th
	Total change (in % points) in P0:							
Total	−0.04	−0.46[a]	−1.38[a]	−2.23[a]	0.21[a]	−0.04[a]	−1.07[a]	−2.65[a]
Non-constrained	0.04	−0.17	−0.97[a]	−1.50[a]	0.19	−0.03	−0.58[a]	−1.78[a]
Constrained	−0.07	−0.53[a]	−1.49[a]	−2.42[a]	0.21[a]	−0.04	−1.20[a]	−2.87[a]
	Change (in % points) in P0 due to change in:							
Wage	−0.13[a]	−0.38[a]	−1.09[a]	−1.51[a]	0.17[a]	−0.01	−0.74[a]	−1.87[a]
Self-employment revenue	−0.10[a]	−0.22[a]	−0.79[a]	−1.07[a]	0.06[a]	−0.04[a]	−0.55[a]	−1.34[a]
Own-consumption	−0.03	−0.10[a]	−0.19[a]	−0.27[a]	0.06[a]	0.00	−0.15[a]	−0.47[a]
Consumer prices	0.21[a]	0.36[a]	0.68[a]	0.79[a]	−0.04[a]	0.01	0.43[a]	1.07[a]
Residual	0.01	−0.12	0.01	−0.17	−0.04	0	−0.06	−0.04
Rural households P0 (wrt base year, %)	28.51							
	Foreign financing				**Tax financing**			
Period	1st	5th	20th	100th	1st	5th	20th	100th
	Total change (in % points) in P0:							
Total	−0.05	−0.51[a]	−1.59[a]	−2.58[a]	0.23[a]	−0.05	−1.23[a]	−3.06[a]
	Change (in % points) in P0 due to change in:							
Wage	−0.13[a]	−0.42[a]	−1.23[a]	−1.69[a]	0.19[a]	−0.01	−0.82[a]	−2.07[a]
Self-employment revenue	−0.11[a]	−0.26[a]	−0.94[a]	−1.28[a]	0.07[a]	−0.05	−0.66[a]	−1.60[a]
Own-consumption	−0.04	−0.12[a]	−0.23[a]	−0.32[a]	0.07[a]	0.00	−0.18[a]	−0.57[a]
Consumer prices	0.23[a]	0.42[a]	0.79[a]	0.92[a]	−0.05[a]	0.01	0.50[a]	1.23[a]
Residual	0	−0.13	0.02	−0.21	−0.05	0	−0.07	−0.05
Migrant households P0 (wrt base year, %)	2.36							
	Foreign financing				**Tax financing**			
Period	1st	5th	20th	100th	1st	5th	20th	100th
	Total change (in % points) in P0:							
Total	0.02	−0.26[a]	−0.39[a]	−0.43[a]	0.02	0.00	−0.3[a]	−0.53[a]
	Change (in % points) in P0 due to change in:							
Wage	−0.16	−0.17	−0.27[a]	−0.44[a]	0.03	0.00	−0.23[a]	−0.46[a]
Self-employment	−0.01	−0.05	−0.13[a]	−0.17[a]	0.00	0.00	−0.11[a]	−0.17[a]
Consumer prices	0.03	0.03	0.03	0.03	0.00	0.00	0.03	0.03
Residual	0.16	−0.07	−0.02	0.15	−0.01	0	0.01	0.07
Urban household P0 (wrt base year, %)	6.60							
	Foreign financing				**Tax financing**			
Period	1st	5th	20th	100th	1st	5th	20th	100th
	Total change (in % points) in P0							
Total	−0.03	−0.20[a]	−0.38[a]	−0.58[a]	0.09[a]	−0.01	−0.32[a]	−0.65[a]
	Change (in % points) in P0 due to change in:							
Wage	−0.14[a]	−0.21[a]	−0.42[a]	−0.70[a]	0.09[a]	0.00	−0.32[a]	−0.91[a]
Self-employment	−0.04	−0.04	−0.07[a]	−0.07[a]	0.00	−0.03	−0.06[a]	−0.1[a]
Consumer prices	0.08[a]	0.09[a]	0.18[a]	0.19[a]	−0.01	0.01	0.10[a]	0.29[a]

(continued)

Table 10 (continued)

National P0 (wrt base year, %)	24.70							
	Foreign financing				Tax financing			
Residual	0.07	−0.04	−0.07	0	0.01	0.01	−0.04	0.07

Note: The base poverty headcount indexes of the constrained and non-constrained households are respectively 24.67 % and 24.84 %

[a]The difference relative to the base year is statistically significant at the 10 % level

in both the short run and long run. In the long run, for example, the overall poverty headcount ratio falls by 2.23 percentage points in the foreign borrowing scenario (scenario 1), and by 2.65 percentage points in the production tax scenario (scenario 2). The poverty headcount for rural households falls by 2.58 percentage points in the long run in scenario 1 and by 3.06 percentage points in scenario 2. The poverty reductions among urban and migrant households are also quite significant. For example, under the production tax financing mechanism, the poverty headcount ratios for migrant and urban households respectively decline by 0.53 and 0.65 percentage points in the long run. We also tested whether the poverty reductions relative to the base year are statistically significant using the approach in Araar and Duclos (2009). The test results are reported in Table 10. For the national sample, all poverty reductions are relative to the base year and, except for in the first period in scenario 1, are statistically significant at the 10 % level.

Higher PII is found to have different poverty effects on constrained and non-constrained households in the first period. For example, under the foreign financing mechanism, some non-constrained households exit poverty in the first period (headcount decreases by 0.07 percentage points), while some constrained households enter poverty (their headcount ratio increases by 0.04 percentage points). However, both changes relative to the base year are not statistically significant. The results show that poverty is reduced in the long run for both types of households, by 2.42 percentage points among constrained households and by 2.50 percentage points among non-constrained households. The result indicates that the increased PII has larger poverty reduction effects for constrained households than for non-constrained households, which is consistent with the macro effects. This is likely because most of the poor among constrained households are near the poverty line than among non-constrained households, making it easier for them to exit poverty. Many factors positively and negatively interact with the effects of PII on poverty (Table 10). The poverty reducing effects of PII largely arise from two sources: wage income and income from self-employment. In the long run, wages contribute to decrease the national poverty headcount ratio by 1.51 percentage points under scenario 1 and by 1.87 percentage points under scenario 2. As shown with respect to macro effects, wages rise rapidly, by 4.81 % in scenario 1 and by 5.74 % in scenario 2. It is worth noting here that wage income is the most important source of income among many poor households. Approximately 60 % of households in the sample earn wage income. The rise in self-employment income is the second largest contribution to poverty reduction. Rising self-employment income reduces the long run national poverty headcount by 1.07 percentage points

in scenario 1 and by 1.34 percentage points in scenario 2. The increasing effects of PII on poverty are largely due to rising consumer prices. The results show that, in the long term, the rise of consumer prices induced by the PII contributes to increase the national poverty headcount by 0.79 and 1.07 percentage points under scenario 1 and scenario 2 respectively.

Effects on Inequality: Gini Coefficient

The Gini coefficient is used to show the effects of higher PII on inequality (see Table 11). The Gini coefficient in the base year is noted at the national level (0.3292) and among rural (0.3021), urban (0.3089) and migrant (0.2862) households. Real consumption expenditures are used to estimate Gini coefficients in this study, so the coefficients are smaller than those reported in studies that use real income.

Similar to the poverty effects, the inequality effects differ by scenario in the first period: equality improves under the foreign financing scenario (national Gini falls to 0.3288), while inequality worsens under the production tax financing scenario (Gini rises to 0.3293). The first of these effects is statistically significant, but the second is not. In both the short and long run, the gradually higher productivity due to higher public investment positively affects equality in the production tax financing scenario. For example, the national Gini coefficient falls to 0.3271 in the short run and 0.3267 in the long run under the production tax financing scenario. Both of these changes are statistically significant.

Table 11 also shows the effects of PII on inequality by household group. Equality improves among both rural and urban households in the short and long run. For example, the long run Gini coefficients among rural and urban households respectively fall to 0.3004 (from 0.3021 in the base year) and 0.3078 (from 0.3089 in the base year) under the foreign financing scenario. Both decreases relative to the base year are statistically significant. However, we should mention that the inequality-reducing effect of the increased PII on migrant households is not statistically significant.

Rising rural–urban inequality is an important issue for the government. The government aims to narrow the gap between rural and urban households. The national Gini coefficient is decomposed to reveal the differing effects of higher PII on rural and urban households. The results show that the Gini coefficient between rural and urban households declines over time (see Table 11). The decrease in inequality between urban and rural areas contributes the most to the improvement in overall inequality in the long run.

Conclusion and Policy Implications

An integrated macro–micro simulation method is applied to analyze the growth and distributive effects of PII. An inter-temporal dynamic CGE model of China is developed to trace the channels whereby PII impacts economic development. The macro effects are passed on to the microsimulation model to analyze the poverty

Table 11 Effects of increased public infrastructure investment on inequality

	Base year	Foreign financing				Production tax financing			
Period	Gini coefficient	1st	5th	20th	100th	1st	5th	20th	100th
Group									
National	0.3292	0.3288[a]	0.3285[a]	0.3277[a]	0.3271[a]	0.3293	0.3290[a]	0.3281[a]	0.3267[a]
Rural	0.3021	0.3018[a]	0.3015[a]	0.3009[a]	0.3004[a]	0.3023[a]	0.3020[a]	0.3012[a]	0.3001[a]
Migrant	0.2862	0.2862	0.2864	0.2872	0.2877	0.2861	0.2862	0.2868	0.2884
Urban	0.3089	0.3086[a]	0.3084[a]	0.3081[a]	0.3078[a]	0.3090	0.3089[a]	0.3083[a]	0.3076[a]
Within	0.1964	0.1959	0.1957	0.1954	0.1952	0.1961	0.1960	0.1955	0.1950
Between	0.0954	0.0948	0.0947	0.0943	0.0938	0.0950	0.0949	0.0945	0.0936
Overlap	0.0373	0.0370	0.0370	0.0370	0.0370	0.0371	0.0370	0.0370	0.0370

[a]The difference (relative to the base year) is statistically significant at the 10 % level

Source: Simulation results

and inequality effects. A 20 % increase in the PII-to-GDP ratio is simulated and two different financing mechanisms are considered to finance this additional PII: foreign borrowing and a production tax.

Although some first-year results differ in their responses to higher PII in China, the two simulation results are similar in both the short run and long run. For instance, the increase in PII has a small crowding out effect on private investment in the first period when a production tax is used to finance the PII, whereas there are virtually no negative effects under the foreign borrowing mechanism. The results show that the increase in PII not only drives economic growth, but also helps reduce poverty and inequality. Long run real GDP is found to be approximately 4 percentage points higher in response to increased PII, as a result of improved long run productivity. Sector-specific characteristics cause sectors to respond differently. For example, the construction, nonmetallic mineral products, and metal and metal products sectors gain significantly from the increased PII, while the labour-intensive textiles sector loses a degree of competitiveness due to rising real wages.

In particular, PII leads to significant and positive improvements in poverty and inequality in both the short run and long run. The national poverty headcount ratio (international line of $1.25/day) is more than 2 percentage points lower in the long run. Rising wages contribute the most to poverty reduction. As expected from the initial distribution of the poor within the country, the results also show that most of the people exiting poverty are from rural areas. Equality improves both among and between rural and urban households.

The conclusion that infrastructure both raises growth and lowers income inequality implies that infrastructure development may be a key win-win ingredient for poverty and inequality reduction. In addition to raising society's overall economic growth, it also helps raise the share of income earned by the poor. This suggests that infrastructure development should rank as a top priority in the poverty and inequality reduction agenda in China. In particular, in order to counter rising rural–urban income inequality, improved public infrastructure in rural areas could be a useful strategy. In other words, public infrastructure development should be considered as key strategy for inclusive growth.

Acknowledgements The authors want to acknowledge the financial and technical support from the Partnership for Economic Policy (PEP). PEP is financed by the Department for International Development (DFID) of the United Kingdom (or UK Aid) and the Government of Canada through the International Development Research Center (IDRC). This particular program of research received separate funding from the Australian Agency for International Development (AusAID). We thank participants in several PEP general meetings, the 2013 GTAP annual conference in Shanghai, the 2013 GDN annual conference in Manila and the 2012 international conference on CGE modeling – "Urbanization and Sustainable Development" – in Beijing for helpful comments. We also salute the support and advice provided by governmental and non-governmental counterparts. Dr. Chen's participation in the project was supported by China Contribution to International Food Policy Research Institute (IFPRI). The authors are also grateful to Jean-Yves Duclos, John Cockburn, Yazid Dissou, Luca Tiberti and Selma Didic for their technical support and guidance.

Appendix

Table A1 Parameters used in CGE model

Parameters	Elasticity of substitution in the first level of nested CES production functions	Elasticity of substitution in the second level of CES production functions	Elasticity of substitution in the second level nest of CES production functions	Elasticity of substitution in the 1st level nest of Armington functions	Elasticity of substitution in 1st level nest of CET functions	Capital depreciation rate for non-constrained firms (%)	Capital depreciation rate for constrained firms (%)	Public capital production elasticity
Agriculture	0.1	0.45	0.4	3	3.6	1.6	5	0.15
Mining	0.1	0.65	1.2	3.7	4.6	5.2	5	0.15
Food processing	0.1	0.65	1.2	2.1	4.6	5.2	5	0.15
Textiles	0.1	0.65	1.2	3.8	5.4	5.2	5	0.15
Other manufacturing	0.1	0.65	1.2	3.3	3.8	5.2	5	0.15
Electric power, heat power and water	0.1	0.65	1.2	2.8	3.8	5.2	5	0.15
Coking, gas and petroleum	0.1	0.65	1.2	2.1	3.8	5.2	5	0.15
Chemical industry	0.1	0.65	1.2	3.8	4.6	5.2	5	0.15
Nonmetallic mineral products	0.1	0.65	1.2	3.8	4.6	5.2	5	0.15
Processing of metals and metal products	0.1	0.65	1.2	3.8	4.6	5.2	5	0.15
Machinery and equipment	0.1	0.65	1.2	3.8	4.6	5.2	5	0.15

Construction	0.1	0.65	1.2	1.9	3.8	5.2	5	0.15
Transport	0.1	0.65	1.2	1.9	2.8	4.0	5	0.15
Trade and catering services	0.1	0.65	1.2	1.9	2.8	4.0	5	0.15
Real estate	0.1	0.65	1.2	1.9	2.8	4.0	5	0.15
Finance	0.1	0.65	1.2	1.9	2.8	4.0	5	0.15
Other services	0.1	0.65	1.2	1.9	2.8	4.0	5	0.15

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Public Infrastructure and Economic Growth in Pakistan: A Dynamic CGE-Microsimulation Analysis

Vaqar Ahmed, Ahsan Abbas, and Saira Ahmed

Introduction and Background

The role of infrastructure in economic growth and welfare has been studied extensively across the literature over the past three decades. Post World War II reconstruction presented a model where governments invested in economies in order to create an enabling environment for the private sector. This led to infrastructure being viewed as something along the lines of a public good, and in many countries its provision became the sole responsibility of the state.

Later, many experts realized that infrastructure needs to be divided into public works (mainly construction of infrastructure) and public service delivery (provision of utilities such as electricity and water).[1] While the former remains a public sector domain in developing countries, public service delivery has seen the involvement of the private sector through unbundling of supply chains.

More recently in the wake of commodity price hikes and the global financial crisis, developing countries have found it hard to sustain investment in infrastructure (Planning Commission 2011). This has led to the closure of mega projects, particularly in the energy and water sectors, in association with escalating costs, time overruns, etc. Governments are increasingly turning to alternative modes of financing, including private sector participation such as public private partnership models and build-operate-own models. However, even these modes of financing have proven challenging as most developing countries have yet to come up with a legal and regulatory framework for such transactions. Until such a framework

[1] See World Bank (1994) for more on this.

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J. Cockburn et al. (eds.), *Infrastructure and Economic Growth in Asia*,
Economic Studies in Inequality, Social Exclusion and Well-Being,
DOI 10.1007/978-3-319-03137-8_5, © The Author(s) 2013

exists, infrastructure financing will continue through foreign aid, collecting taxes and imposing development and user charges (Lin 2011).

As a developing country, Pakistan is also faced with infrastructure issues which can be classified into broad headings of quantity, efficiency and financing. Inter- and intra-regional inequalities exist in access to even basic infrastructure. This situation has forced people to migrate to cities in search of increased opportunities. Today, Pakistan has the fastest urbanization rate in all of South Asia. This has put pressures on already stressed urban infrastructure.

In view of the above mentioned, this paper investigates two modes of financing public infrastructure: international borrowing and production taxes. The next section provides a brief literature review on the subject and is followed by discussion of the current state of infrastructure in Pakistan. Section "Data and Parameterization" discusses the data and parameterization. Section "Results" explains our results and the section "Conclusion" concludes with policy recommendations.

Infrastructure and Economic Growth

We divide the literature into two quantitative streams, primarily for methodological ease. The first stream uses econometric tools to study the impact of infrastructure on growth and the second uses a computable general equilibrium model.

Global Evidence

The World Bank (1994) provides important insight into infrastructure dynamics from an availability, efficiency and financing point of view, but it defined infrastructure from the narrow perspective of public services comprised of electricity, energy and water, as well as public works, primarily roads and other transportation infrastructure such as rail, port and airports. The seminal work by Aschauer (1989) shows significant impact of public capital on growth has results which are contrary to those of Holtz-Eakin (1994). Aschauer (1998) later suggested, for the case of Mexico, that large public investments are an insufficient condition for growth, and must be complemented by policies regarding the financing and use of infrastructure. Most of the earlier literature is silent on the impact of infrastructure on poverty and inequality.

Looking at infrastructure through disaggregated spending is also important. Public expenditures on connectivity and ICT play an important role in facilitating growth processes. Connectivity between people and places has been shown to overcome urban–rural, gender and human capital disparities. Lall (2006), taking a pooled dataset of Indian states, shows that spending on transport and communications infrastructure are significant determinants of regional growth. There are positive externalities from investments by local and neighbouring states. Devarajan

et al. (1996) had previously found a negative and significant relationship between economic growth and transport and communications expenditures-to-total expenditures ratio in their sample of countries, and attributed this to the possibility that overinvestment in transport and communications makes such expenditures relatively unproductive. Canning and Pedroni (2008) analyze a panel of countries from 1950 to 1992 and show that infrastructure does not tend to cause growth in the longer run, although there is variation across countries. Infrastructure is undersupplied in some countries and oversupplied in others.

In the same cross-country regression tradition, Sanchez-Robles (1998) used the quantity of public infrastructure stock (measured through indices) rather than public infrastructure expenditures and found a positive and significant relationship. The author stressed the need to ensure the efficiency of public investment for optimal absorption. Accountability and civil service reforms need to be established as part of robust monitoring and evaluation for projects funded through either taxation or foreign aid (Planning Commission 2011).

Straub et al. (2008) show for East Asia that the failure to find a significant link between infrastructure, productivity and growth may arise because investments in infrastructure were made to relieve constraints and bottlenecks (where they existed) rather than to directly encourage growth.

In time-series studies, Nketiah-Amponsah (2009) show for Ghana that aggregate government expenditures over 1970–2004 negatively impacted economic growth. More specifically, disaggregated (short run) health and infrastructure expenditures positively affected growth and education expenditures negatively impacted growth. The political economy variables such as governance and political instability were significant in explaining growth. Sahoo and Dash (2009) also show for India that the stock of infrastructure positively contributes to growth with unidirectional causality from infrastructure development to output growth.

Some existing CGE studies investigate the economy-wide impact of public infrastructure. Rioja (2001), in general equilibrium studies on Brazil, Mexico and Peru, show that these countries underinvested in infrastructure during 1970s and 1980s. The simulations suggest that infrastructure can positively impact output, private investment and welfare.

Estache et al. (2009) show for Mali that foreign aid-funded infrastructure does produce Dutch Disease effects, but that the negative impacts differ by the type of investment, while economic growth attenuates these negative effects.

Dissou and Didic (2011) found for Benin that the crowding out effects of public infrastructure is sensitive to the mode of financing chosen by the government. Overall, their findings suggest that public investment in infrastructure can support private investment and sustain capital accumulation. The positive impact of public investment on private investment can be explained through the infrastructure financing channels such as public private partnerships and sub-contracting which in turn tend to crowd-in private investment.

Pakistan's Context

In the case of Pakistan there are several studies showing a negative or insignificant impact of aggregate public investments on growth. These include Ghani and Din (2006), Rehman et al. (2010) and the Planning Commission (2011). Sadly, not enough work has been done to quantify the economy-wide impact of public expenditures at a disaggregated level. However, some background studies do estimate the infrastructure deficit in Pakistan (Samad and Ahmed 2011).

World Bank (2007) reported that Pakistan's key infrastructure shortages lie in the water, irrigation, power and transport sectors. The country is amongst the most water-stressed in the world and rehabilitating current wear and tear in the water sector will require more than $7 billion in maintenance over the next 5 years. Pakistan faces severe power shortages of approximately 5,000 MW and per capita energy consumption is among the lowest in the world, slowing industrial growth. The inefficiencies of the rail, road, port and aviation sectors are now costing the economy over 4 % of GDP.

While various governments have tried to pump capital in maintenance and incremental infrastructure with the help of development partners, capacity to implement these programs has remained weak. The lack of suitable human resources, poor planning and management skills and an inability to attract external implementation resources has led to time and cost overruns. Over half of the annually trained engineers migrate abroad for employment (due to significant wage differences) and declining economic growth has made it impossible to attract them back (Mehmood et al. 2013). Corruption in infrastructure projects has been estimated to be 10–15 % of the project value. The average project runs three times longer and two times more expensive than the initially planned cost (Pasha 2011). This is attributed to: external verifications (National Accountability Bureau, Chief Minister's Inspection Teams, Parliamentary Committees etc.); audit procedures; local government procedures (mining, land acquisition, forest department etc.); law enforcement agencies; and corruption.

ADB (2008) explains that Pakistan had a successful experience with privatization of state-owned telecom enterprise. This not only attracted foreign direct investment but also ensured efficiency through competition. However, excessive regulation has impeded replication of this experience across other sectors, such as energy, where the government continues to subsidize operations. Also see SBP (2007) for more details in this regard. JBICI (2007) describes how productivity is declining among 45 % of workers, primarily in the agricultural sector, due to the dilapidated state of irrigation infrastructure. The report shows that access to irrigation infrastructure helps to keep the incidence of chronic poverty at lower levels. Furthermore, improving, lining and upgrading watercourses will help improve water efficiency.

Pakistan faces a major threat from climate change. The country has witnessed regular instances of floods, droughts and earthquakes. The Asian Development Bank, World Bank and the One UN office jointly conducted the damage assessment

for the 2010 floods and reported aggregate damages of PKR 855 billion. The reconstruction costs (which includes rebuilding/renovating lost infrastructure) range from an estimated US$6.8 to 8.9 billion. The report recommends that this should be seen as an opportunity to build stronger and energy efficient infrastructure for future growth and welfare.

Recent Issues

Infrastructure affordability: Sustaining infrastructure growth has been difficult for developing countries over the medium to long run. Lin (2011) identifies three reasons for the slowdown of infrastructure growth in China after 1978. These include: low government spending, decreased investment incentives for state enterprises and diminished ability of local government to mobilize rural resources. Alternative infrastructure financing mechanisms mentioned by the authors include domestic and foreign debt, taxes, fees and user charges, profits of state enterprises and labour services.

Complementary Reforms: Dodonov et al. (2002) analyze transition countries (with special reference to Ukraine) and show that infrastructure reforms in these countries should be linked with tariff reforms along with an overall national policy of open commercialization and deregulation of infrastructure sectors. A failure to do so may prevent absorption of public and private funds into infrastructure development.

Macroeconomic stabilization: Increased globalization has rendered many developing countries prone to terms of trade shocks. The usual prescription given by multilateral organizations for countries finding themselves in balance of payments difficulties is contradictory fiscal policy. Ramirez (2004) questions stabilization policies in developing countries which disproportionately reduce public infrastructure spending in order to comply with reductions in fiscal deficits.

General equilibrium effects: It is important to note the relative superiority of general equilibrium models in studying the economy-wide, sectoral and disaggregated impacts of infrastructure investment and endowment. Several studies providing such important insights should be mentioned here: Giesecke et al. (2008) who study macroeconomic outcomes under alternative public infrastructure financing arrangements (also see Boccanfuso et al. 2012); Adam and Bevan (2006) look at the role of aid in public investment and possible Dutch disease effects (also see Levy 2007).

Table 1 Global infrastructure ranking, 2011–2012

	Transport	Electricity and telephony	ICT	Education	Health	Security	Public institutions
Malaysia	14	48	57	91	52	48	32
China	29	69	74	93	71	68	46
India	35	116	117	109	109	89	72
Sri Lanka	52	79	100	89	61	59	49
Pakistan	80	126	111	126	111	137	111
Philippines	104	101	93	83	97	117	112
Benin	115	118	120	123	120	95	91
Bangladesh	117	137	132	118	107	103	112

Source: Global competitiveness report, 2011–2012

State of Infrastructure in Pakistan

Infrastructure provides a backbone that sets an economy on the path towards sustained economic growth. The provision of basic and efficient infrastructure in transport, communications and utilities such as electricity provides an enabling environment for the private sector which then takes the lead in the growth process. Table 1 paints a dismal picture for Pakistan in terms of its global infrastructure ranking. While Pakistan has invested in public assets, poor governance (poor accountability, monitoring, stakeholder participation, etc.) continues to plague these assets (Planning Commission 2011).

Infrastructure in Pakistan was traditionally financed through public sector financing, much of which was actually leveraged through foreign aid. However given the rise in global commodity prices, and in particular its effects on input costs in the construction sector, it became almost impossible for the government to afford the rising unit cost of infrastructure financing. In the late 1990s, it was realized that Pakistan would not even be able to maintain the existing infrastructure without deregulating, privatizing and liberalizing this sector for domestic and foreign private investment. In absolute terms, these measures did increase capital formation in the transport and communication sectors.

Road Transport

For transportation, Pakistan relies heavily on roads which handle 96 %[2] of total freight traffic.[3] The federal budget also exhibits a strong bias towards financing construction and maintenance in the road sector. Since 1996, the total length of roads has increased by 13 % to 259,618 km in 2010, 179,290 of which were paved

[2] Economic Survey of Pakistan, 2009–2010.

[3] This section draws from our companion paper Haque et al. (2011).

(referred to as high type). The national highways and motorways network constitutes 4.2 % of the total road network and handles more than 85 % of all road traffic in Pakistan. The majority of Pakistan's highways and motorways network is along the North–south corridor with the N-5 acting as the main artery and carrying 55 % of inter-city traffic in the country. Around 60 % of the network is in poor conditions. This is mainly due to poor maintenance, vehicle overloading, overinflated truck tires and the significant shift from railways to roads in both passenger and freight transport.

Over the past few years, there has been a gradual increase in the length of high type roads and a decline in low type roads (unpaved), with most low type roads being converted to high type (Table 2). The National Highway Authority (NHA) has been carrying out extensive road development projects: 30 new projects to extend the road network by 1,000 km inclusive of bridges, flyovers, and interchanges have started. The NHA has also managed to increase its toll revenue by 36 % over the past year.

Another problem in road transportation is the corruption in the policing system. Traffic laws are lax in Pakistan and the policemen are often underpaid and have long working hours. Corruption is also rampant on the infrastructure development side of road transportation. Roads are often deliberately left weak, susceptible to rapid deterioration, so that contracts can be repeatedly given to the same people.

For the impact and transmission channels of how investment in road infrastructure leads to productivity, economic growth and poverty reduction, we can look to Montolio and Solé-Ollé (2009) and Fan and Chan-Kang (2005). In the case of Pakistan, see Siddiqui (2008) and Chohan et al. (2011).

Rail Transport

Railways around the world have an edge in long haul and mass transportation of both goods and passengers. In Pakistan, it was the primary mode of transport until the 1970s. Since then its share has declined due to the shift in government's preference towards road rather than rail transport. Over 2005–2010, budget expenditures on railways totalled just PKR 45.5 billion whereas for national highways it stood at PKR 155 billion. Its share of inland traffic has fallen from 41 to 10 % of passengers and from 73 to 4 % of freight traffic.

Timely and safe transportation of merchandise from the port in the south for delivery in the north is a major issue given the poor infrastructure in road, rail, warehousing, etc. After the creation of the National Logistic Cell (NLC) to clear the goods from Karachi port, Pakistan Railways (PR) has always found it difficult to maintain its historical position. In Table 3, we see a gradual decrease in the number of passengers and freight moved as well as the length of track and the number of wagons and locomotives.

Table 2 Road sector in Pakistan, 1997–2009

	High type		Low type		Total	
Year	Length	% change	Length	% change	Length	% change
1997	126,117	6.5	103,478	3.6	229,595	5.2
1998	133,462	5.8	107,423	2.5	240,885	4.9
1999	137,352	2.9	110,140	−4.4	247,484	2.7
2000	138,200	0.6	105,320	−2.4	240,340	−2.9
2001	144,652	4.7	102,784	−3.7	249,972	4.0
2002	148,877	2.9	98,943	−1.4	251,661	0.7
2003	153,255	2.9	97,527	−2.2	252,168	0.2
2004	158,543	3.5	95,373	−4.1	256,070	1.5
2005	162,841	2.7	91,491	−5.6	258,214	0.8
2006	167,530	2.9	86,370	−2.7	259,021	0.3
2007	172,827	3.2	84,038	−1.1	259,197	0.1
2008	175,000	1.3	83,140	−3.4	259,038	−0.1
2009	177,060	1.2	80,328	2.5	260,200	0.4

Source: Economic survey of Pakistan, 2009–2010

Table 3 Pakistan rail sector

Rail sector indicators	1991	2009	% change
Route travelled (km)	8,775	7,791	−11.2
Passengers carried (millions)	84.9	82.54	−2.8
Freight carried (million tonnes)	7.72	6.94	−10.1
Locomotives	753	551	−26.8
Freight wagons	34,851	17,259	−50.5

Source: Pakistan Railways 2011

A significant reduction in business activity during the last year partially attributable to security issues, ultimately reducing government revenues. There has also been a shortage of active locomotives due to non-procurement of spare parts. Much of the rolling stock damaged during the December 2007 riots has yet to be repaired. This delay has been mainly due to a reduction in Public Sector Disbursement Program disbursements and slow corporatization. The majority of the engines recently acquired from China are also facing maintenance issues leading to closure of several routes. Earnings are still low and are hardly enough to cover the cost of salaries and pensions, respectively equal to PKR 14 billion and PKR 7 billion per annum. In 2008–2009, earnings grew by 16 % compared to the year before but since have worsened to pre-2004 levels. Despite improved performance during the last decade, losses remain high, at PKR 10 billion in 2006–2007 and over PKR 12 billion in 2007–2008.[4]

[4] For detailed discussion of the growth and productivity effects of rail infrastructure investment, see Crafts (2011) and Banister and Thurstain-Goodwin (2010).

Aviation

In 2007–2008, Pakistan's 35 airports handled more than 14 million passengers and 318,652 million tons of cargo.[5] Jinnah International Airport in Karachi is the busiest, but the Lahore and Islamabad airports also handle significant amounts of domestic and international traffic.

Compared to 2005–2006, both cargo and passenger traffic have fallen. Total passenger traffic has declined by 0.4 million passengers and cargo traffic decreased from 347,674 to 318,652 million tons. Most of this is attributed to the reduction in domestic traffic associated with the poor situation regarding the economy, political instability and law and order.

The total number of domestic and international airlines operating in Pakistan (28) remained the same, although two Pakistani airlines (Aero Asia and Royal Airlines) are no longer in business. This is attributed not only to mismanagement but also to the government's close association with state-owned Pakistan International Airlines (PIA) and the uncompetitive environment for other domestic airlines. PIA accounts for 73 % of all passenger traffic and captures nearly the entire market for freight in the aviation sector. International routes are covered by frequent flights to the UK and Middle Eastern countries. Demand on these routes mainly comes from Pakistani workers abroad. Connections to other countries generally remain infrequent and time consuming.

Due to extra security checks on airlines flying via Pakistan and the recent slowdown in the aviation sector, international airlines largely remain hesitant to explore the Pakistani market. Currently, no Pakistani airline flies direct to any African or Latin American country and the only flights connecting the country to Southeast Asia are two direct flights per week to Malaysia. Connecting flights to other destinations are available but it takes much longer and arrival times are highly uncertain.

Domestic connectivity is also constrained by inadequate airport handling and slow check-in procedures. This leads to lengthy flight delays, making air travel highly inconvenient, particularly given the much higher ticket prices. The domestic market is strong dominated by PIA as a result of preferential route allocation, tax benefits and other protectionist policies, making it difficult for new carriers to enter the aviation sector.[6]

[5] Civil Aviation Authority. http://www.caapakistan.com.pk/, access October 12th, 2012.

[6] For discussion on how air transport infrastructure investment facilitates economic growth, see Hong et al. (2011) and Marazzo, Scherre and Fernandes (2010). For Pakistan see Haque et al. (2011).

Table 4 Electricity production (megawatts)

Year	Installed capacity (MW)	Generation (MW)
2001–2002	17,799	8,265
2002–2003	17,798	8,639
2003–2004	19,257	9,235
2004–2005	19,384	9,787
2005–2006	19,450	10,705
2006–2007	19,420	11,231
2007–2008	19,420	10,943
2008–2009	19,786	10,484
July–March		
2008–2009	19,575	6,940
2009–2010 (e)	19,650	7,517

Source: Economic survey 2009–2010

Energy

Pakistan has been facing significant energy shortages since 2008–2009. The main issue has been the complicated market structure, not capacity constraints. Between 2003 and 2007, energy prices were held fixed, making the private sector more dependent on government subsidies to accommodate variable production costs. Sharp increases in oil and gas prices throughout 2008 put enormous upward pressure on cost structures in the power generation sector. Since tariffs also remained unchanged, much of this burden had to be borne by the government in the form of increased subsidies. However, rising costs in the war on terror along with a slowdown in GDP growth reduced government resources, ultimately leading to the emergence of the inter-corporate debt problem.

Table 4 shows that electricity generation began to decline from 2006 to 2007 onwards despite an increase in overall installed capacity during the same period. Fortunately, data for the last 2 years (shown only for July–March in these 2 years) shows a positive trend.

Despite frequent increases in electricity tariffs in the last 2 years, a wide gap still exists between generation cost and recovery. Before the increases in tariffs, this gap was estimated at around 30 %. Steps towards elimination of subsidy-based tariff regime have helped reduce inter-corporate debt to 120 billion PKR as of May 2010 compared to 216 billion rupees in June 2009.[7]

[7] The link between demand for energy and economic growth has been studied at length in Lee and Chang (2008), Apergis and Payne (2009) and Wolde-Rufael (2008). For Pakistan's case see USAID (2007) and Hye and Riaz (2008).

Water and Sanitation

The quality of physical infrastructure continues to deteriorate and its coverage is exceedingly inequitable; the poor stand deprived and disadvantaged, and pay exorbitant prices to water vendors. The present coverage of water and sanitation facilities are respectively said to be 85 and 65 % in urban areas, but the accuracy of these statistics is often questioned.

Management of service delivery is also a big issue. An important deficiency in this regard has been a lack of local government capacity to generate enough funds for the operation and maintenance of existing networks. There are often no incentives for improved operations and management (O&M) and assets tend to deteriorate much earlier than their usual life. For major projects, local governments are dependent on the assistance of provincial and federal governments. Public sector investment in the sector is very low, at 0.25 % of GDP. In spite of the government's interest in and encouragement of private sector involvement, its' participation has been low.

Local governments suffer technical, financial and administrative weaknesses in planning and in operations and maintenance-related issues, especially in relation to energy requirements. These local government departments are both overstaffed and have an insufficiently trained workforce.

Moreover, underground water reserves are depleting rapidly due to high withdrawal and surface water is exposed to municipal discharges and pollution. Cities have increasingly scarce and poor quality water supplies. Meanwhile, a full 35–40 % of water supplies are lost through leakages in water distribution networks. Water treatment facilities are also limited.

Sewage is collected through open drains in most cities, and is then discharged untreated into rivers, streams, lakes and canals. These waterways are often used as sources for urban water supply schemes. Collection through piped networks is limited to few large cities where coverage is also selective and sewage treatment rare. In small towns, open defecation is not uncommon.

Only 5 % of households have proper access to municipal garbage collection systems, and arrangements to dispose of this waste at properly developed landfill sites are often lacking. Uncollected garbage accumulates in the streets and in open spaces between houses, where scavengers extract the reusable and recyclable materials and leave the rest to rot.[8]

Government Infrastructure Strategy

Given low domestic resource mobilization and low expected tax revenues, public investment has been consistently declining. The existing public sector development programme allocates a very high share of its resources to civil work (almost 60 % in

[8] Discussion on investment in the water sector and its impact on economic growth may be seen in Barrios et al. (2010) and Grey and Sadoff (2007). In case of Pakistan, see World Bank (2008).

2011), leaving little for social sectors such as education and health. Public investment has been spread thin across sectors and regions, making it difficult to focus strategy. The governance of public investment also requires immediate attention. Issues such as electricity and gas shortages result from management problems, not capacity limitations.

The government has been advised to unbundle service delivery of most public utilities. Public investment should be prioritized and sequenced. Public sector projects nearing completion should be given priority. Key infrastructure projects for energy, water and transport production inputs will require participation of the private sector, so rules for public private partnerships should be made as straightforward as possible. Finally, projects to remove regional disparities should be initiated, potentially enabling greater labour force participation, particularly in war torn areas.

Due to the fiscal crunch and a lack of coordination between government departments, the National Trade Corridor project was abandoned in 2011. The project had earlier been envisaged as having an integrated focus on transport, logistics and economic growth. The Planning Commission (2011) realized that resource constraints meant that new investment in infrastructure was hard to come by, and that the government should thus shift focus more toward improving management of existing infrastructure. To some extent, this remains true as many public sector monopolies in the provision of infrastructure have underperformed due to structural inefficiencies. This document also talks about deregulating the rail, road and aviation sectors to allow private sector participation. Interest has already been expressed by China, India and other East Asian economies for direct investments in transport, logistics, and oil and gas exploration.

It is pertinent to mention that autonomous or semi-governmental bodies such as WAPDA, OGDCL, etc., outline their own investment plans according to their own resource availability and projected cash flows. Provincial governments also spend directly on infrastructure; some have outlined their infrastructure priorities in provincial economic reports.

Data and Parameterization

The CGE-microsimulation approach adopted for this study is discussed in chapter on The Philippines case study. For more details, refer to Dissou and Didic (2011) for the CGE model and to Cockburn et al. (2011) for the microsimulation module.

The dynamic CGE model is calibrated to the benchmark data in the 2007–2008 Pakistani social accounting matrix, where 12 production sectors and 12 commodities are identified. For the microsimulation model we use the Pakistan Social and Living Standards Measurement Survey (PSLM) 2007–2008. Some of the external parameters used in the CGE model include: substitution elasticity of the CES household function (0.7 %), substitution elasticity of first- and second-level CES production functions (0.5 % and 0.4 %), the depreciation rate (12 %), output elasticity of

public capital (0.3), the share of public investment in total investment (28 %), the population growth rate (1.8 %), the world real interest rate (6 %) and the share of constrained households in: consumption (57 %), labour income (71 %), income taxes (10 %) and government transfers (10 %). Most of these external parameters are in line with previous CGE studies on Pakistan (such as Ahmed and O' Donoghue 2010). For details on comparable discussion of parameters, please see UNIDO (2009).

Simulation design: We simulate a 4 % increase in the public infrastructure investment-to-GDP ratio. This increase brings the public infrastructure investment-to-GDP ratio back to the levels observed prior to the food, fuel and financial crises. This simulation follows the Planning Commission's *Framework for Economic Growth* by studying the impact of a 4 % increase in this ratio financed by either (a) international borrowing or (b) a production tax.[9] We look at the short, medium and long term impacts in both of these policy experiments.[10]

Results

Financing the 4 % increase in the public infrastructure investment-to-GDP ratio by an increase in international borrowing generates a real GDP growth higher right from the very first period because foreign savings finance the borrowing used to increase investment, with a 1.3 % growth in the overall long-run. If we disaggregate by GDP components, total investment and household consumption in the long run are simulated to grow by 3.4 and 1.2 % respectively (Table 5).

Infrastructure investment appears to have redistributive effects, given that the rise in consumption is relatively higher among constrained households than non-constrained households. Additionally, constrained firms in this scenario invest more starting in the first period (again reflecting increased savings available for investment purposes).

Wages rise throughout the time horizon, while the price of capital declines over time. The lower cost of capital facilitates long run expansion of both public (+5 %) and private (+2 %) capital stocks. In the long-run, the private capital stock increases by relatively more among non-constrained firms due to their access to financial services.

[9] The reason for choosing the production tax is that usually, of the many indirect taxes, this is one of the easiest to implement in developing countries with fewer politically unfavorable implications (given that it is linked with growth in value added). However this tax also has highly distortionary effects on production and consumption.

[10] All variables are expressed in "per efficient workers" terms (per capita + technological progress). If we suppose that in the business as usual (BAU) scenario all variables rise by the population growth and technological progress rates, and if we express all variables in "per efficient workers," then under the BAU variables are constant over time and correspond exactly to the base year. All results presented below should thus be read as changes relative to the base year.

Table 5 Macro impacts of 4 % increase in public infrastructure investment-to-GDP ratio (international borrowing), percentage change wrt base scenario

Variable	First period	Short run	Long run
Real GDP	0.31	0.69	1.29
Wage rate	0.23	1.04	2.26
Price of capital goods	0.39	0.35	0.08
Rental rate of capital, constrained households	0.69	1.43	1.31
Total household consumption	0.07	0.46	1.16
Constrained	0.45	0.93	1.58
Non-constrained	−0.07	0.04	0.37
Total Investment	1.65	2.33	3.35
Public	3.92	4.35	5.26
Private	0.75	1.52	2.59
Constrained	0.06	0.58	1.50
Non-constrained	1.05	1.93	3.07
Total capital stock		0.85	2.81
Public		1.81	4.64
Private		0.44	2.01
Constrained		0.13	1.13
Non-constrained		0.59	2.45
Total exports	−0.50	0.23	1.80
Total imports	0.84	1.31	1.93
Real exchange rate	−0.28	−0.24	−0.03
Foreign savings as % of GDP	−2.73	−2.74	−2.83
Total income of constrained households	0.45	0.93	1.58
Labour income	0.23	1.04	2.26
Capital income	0.69	1.57	2.45
Government revenues	1.63	2.03	2.55
Additional foreign borrowing as % of GDP	0.21	0.17	0.09

Source: Authors' computation based on simulation results

On the trade side, the increase in foreign reserves leads to real exchange appreciation. In the first period, this reduces export price competitiveness, indicating a Dutch disease-like effect. In the first period, exports decline by 0.5 % and imports increase by 0.84 %. In the long run, both exports and imports increase because greater availability of investment funds and a higher stock of infrastructure improve supply side conditions. The increase in the international borrowing-to-GDP ratio tapers off (declining by 0.09 % in the longer run) due to reduced borrowing needs to fund incremental infrastructure. This is also attributable to rising government revenues in the long run. The increase in government revenues is higher in the long run (by 3 %) than in the previous simulation because foreign savings have a greater growth impact. The main sources of additional revenue are direct taxes, consumption taxes and import taxes.

Gross output grows by most in the construction and non-textile manufacturing sectors (which are relatively labour intensive), followed by cotton and textiles which are export-oriented sectors (Table 6). Prices decline across the board in the longer run (Table 7), partially explaining the gains in household consumption.

Table 6 Sectoral impacts of 4 % increase in public infrast. investment-to-GDP ratio (international borrowing), percentage change wrt base scenario

	Food crop	Min. crop	Agr prod	Cotton	Livestock	Manufacturing	Energy	Textiles	Construction	T&C	Priv serv	Pub serv
Gross output												
First period	−0.11	−0.03	−0.11	−0.36	−0.03	−0.06	−0.15	−0.37	0.79	−0.02	0.01	−0.07
Short run	0.39	0.49	0.45	0.35	0.47	0.61	0.32	0.34	1.32	0.38	0.31	−0.05
Long run	1.44	1.44	1.54	1.88	1.54	1.94	1.25	1.86	2.22	1.11	0.91	0.11
Investment												
First period		0.73	0.67	0.24		0.97	0.43	0.32		1.18	1.20	
Short run		1.36	1.40	1.50		1.81	1.23	1.54		2.09	2.06	
Long run		2.17	2.31	2.87		2.92	2.16	2.87		3.53	3.44	
Exports												
First period	−0.74	−0.43	−0.57	−0.38	−0.81	−0.42		−0.60		−0.39	−0.50	−0.57
Short run	0.08	0.44	0.30	0.37	0.22	0.31		0.17		0.13	−0.34	−1.25
Long run	2.31	2.05	2.18	2.04	2.91	1.87		1.91		1.12	0.18	−1.94
Imports												
First period	1.19	0.85	1.13	−0.31	1.53	0.92	0.41	0.69			0.91	0.87
Short run	1.05	0.60	0.84	0.28	0.98	1.41	0.67	1.11			1.47	2.17
Long run	−0.32	0.11	−0.14	1.44	−1.15	2.14	1.05	1.59			2.21	3.88
Domestic demand												
First period	−0.10	−0.01	−0.01	−0.36	−0.03	0.02	−0.15	−0.17	0.79	0.04	0.01	−0.07
Short run	0.40	0.50	0.48	0.34	0.47	0.68	0.32	0.48	1.32	0.43	0.31	−0.04
Long run	1.43	1.40	1.40	1.84	1.54	1.96	1.25	1.81	2.22	1.11	0.91	0.13
Consumption												
First period		0.12	0.07	0.25	−0.01	0.18	0.18	0.12	−0.21	0.11	0.09	0.10
Short run		0.55	0.51	0.58	0.48	0.50	0.52	0.46	0.18	0.46	0.35	0.17
Long run		1.25	1.30	1.10	1.51	1.02	1.07	1.07	1.05	1.04	0.79	0.36
Demand for intermediate use												
First period	−0.08	−0.05	−0.07	−0.36	−0.06	0.13	−0.06	−0.33	0.18	−0.06	−0.06	−0.07
Short run	0.41	0.43	0.44	0.33	0.47	0.65	0.37	0.34	0.57	0.37	0.40	0.38
Long run	1.40	1.38	1.46	1.83	1.54	1.63	1.22	1.76	1.30	1.24	1.31	1.31

Source: Authors' computation based on simulation results

T&C transport and communications, food crop, minor crop, livestock and agr prod are constrained sectors

Table 7 Price impact of 4 % increase in public infrastructure investment-to-GDP ratio (international borrowing), percentage change wrt base scenario

	Food crops	Minor crops	Agri processing	Cotton	Livestock	Manufacturing	Energy	Textiles	Construction	T&C	Priv. serv.	Pub. serv.
Price of gross output												
First period	0.14	−0.21	−15.12	−12.4	0.39	−15.86	−34.38	5.17	0.46	−0.27	0.68	−6.12
Short run	−0.02	−0.38	−15.25	−12.4	0.13	−15.89	−34.41	5.13	0.35	−0.33	0.76	−5.78
Long run	−0.60	−0.70	−15.58	−12.5	−0.67	−15.98	−34.50	5.02	−0.23	−0.46	0.79	−5.38
Price of domestic goods												
First period	0.32	0.21	0.28	0.01	0.39	0.22	0.14	0.22	0.67	0.22	0.26	0.25
Short run	0.16	0.03	0.09	−0.02	0.13	0.18	0.09	0.16	0.56	0.15	0.33	0.61
Long run	−0.43	−0.32	−0.38	−0.10	−0.67	0.04	−0.05	−0.05	−0.02	0.00	0.37	1.05
Price of composite goods												
First period	0.32	0.20	0.27	0.01	0.39	0.12	0.11	0.20	0.67	0.22	0.25	0.23
Short run	0.16	0.03	0.09	−0.02	0.12	0.10	0.07	0.15	0.56	0.15	0.32	0.56
Long run	−0.43	−0.30	−0.37	−0.09	−0.66	0.02	−0.04	−0.05	−0.02	0.00	0.35	0.96
Shadow price of capital												
First period		0.54	0.53	0.44		0.60	0.48	0.46		0.64	0.65	
Short run		0.54	0.55	0.59		0.60	0.53	0.59		0.64	0.64	
Long run		0.16	0.16	0.20		0.18	0.16	0.19		0.21	0.21	

Source: Authors' computation based on simulation results

T&C transport and communications

Under a policy experiment of infrastructure financed through international borrowing, poverty reduction can be observed from the very beginning (Table 11), with higher wages contributing the most to poverty reduction, followed by increased self-employment incomes (Table 12).

Poverty is lower in the long run among both household types, but the relative improvements in the poverty headcount are higher among constrained households (Table 13). The provincial poverty incidence results show that poverty reductions are greatest in the Punjab and Sindh provinces (Table 14). The international borrowing scenario is redistributive, with inequality falling throughout the time horizon (Table 15).

Unlike the previous simulation, financing the 4 % increase in the public infrastructure investment-to-GDP ratio by an increase in taxes strains real GDP growth in the first period (−0.06 %). However, growth recovers in the short-run (within 5 years) and is 1 % higher than the baseline scenario in the longer-run (Table 8), but below the rates predicted for the international borrowing scenario along the whole simulation timespan. Total consumption follows a similar pattern: the increased tax burden causes total household consumption to decline by 0.1 % in the first period, but is 0.94 % higher in the longer run. As in the previous simulation, total household consumption is redistributed somewhat, with increased taxes implying greater gains for constrained households (1.2 %) than for non-constrained households (0.2 %), which have access to savings instruments. This is primarily due to an increased incidence of tax on non-constrained households who own enterprises facing the distortionary production tax. This tax mostly affects large manufacturing firms, which are mostly in food processing-, textiles- and construction-related industries.

The main increase in overall investment comes from public investment, which is 5 % higher in the longer run. There are also positive knock-on effects on private investment, which increases by 2.3 %, providing evidence of a crowding-in effect.[11] In the private sector, investment by non-constrained firms is 2.7 % higher in the long run. While constrained firms also gain in the short run and beyond, their investment declines by 0.27 % in the first period. This can be attributed to the lagged transmission of the increase in overall pool of savings to be used for investments by constrained firms, which in the model are assumed to be financed by own retained earnings.[12]

The price of capital and labour move in opposite directions whereby the former increases in the short run but declines in the long run, in turn resulting in greater capital formation.[13] This may be attributed to the increased tax burden which

[11] It is important to note that private investment is higher despite a production tax due to complementarities in public and private investment. However, in the short term there is a negative impact on private investment at the disaggregated level and a null effect on the capital stock.

[12] The positive externality of public investment in terms of expansion in private capital stocks is around 1.7 % in the long run.

[13] The complementarity of private capital linked to the public capital rises and this produces an implicit surplus of private capital in the long run, thus pushing the price or returns to private capital downwards. Also, labour becomes relatively more rare, pushing wages upwards.

Table 8 Aggregate impacts of 4 % increase in public infrastructure investment-to-GDP ratio (tax financing), percentage change wrt base scenario

Variable	First period	Short run	Long run[a]
Real GDP	−0.06	0.33	1.01
Wage rate	−0.32	0.51	1.86
Price of capital goods	0.12	0.14	−0.02
Rental rate of capital, constrained households	0.02	1.02	1.24
Total household consumption	−0.11	0.25	0.94
Constrained	−0.15	0.38	1.19
Non-constrained	−0.09	−0.04	0.18
Total Investment	1.29	1.99	3.07
Public	3.81	4.19	5.07
Private	0.29	1.11	2.27
Constrained	−0.27	0.24	1.21
Non-constrained	0.54	1.50	2.74
Total capital stock		0.71	2.53
Public		1.76	4.47
Private		0.26	1.69
Constrained		−0.02	0.84
Non-constrained		0.40	2.11
Total exports	−0.19	0.45	1.88
Total imports	0.37	0.89	1.58
Real exchange rate	0.03	0.01	0.12
Foreign savings as % of GDP	−2.68	−2.70	−2.82
Total income of constrained households	−0.15	0.38	1.19
Labour income	−0.32	0.51	1.86
Capital income	0.02	1.00	2.09
Government revenues	1.18	1.62	2.26
Increase in production tax rate (%)	3.43	3.03	1.73

Source: Authors' computation based on simulation results
[a]In case of CGE results long run represents a 60 year period

reduces retained earnings in the short run, although the increase in public investment afforded by increased taxation in the longer run leads to greater capital formation and ultimately economic growth through a multiplier effect. The wage rate slumps by 0.32 % in the first period, recovers in the short run and is nearly 2 % higher in the longer run. The differences in the increased usage of production factors can also be attributed to the distortionary effects of the increased production tax.

The external balance, measured as foreign savings as a ratio of GDP, remains in the vicinity of 3 %. The key changes are seen in the trade account. Despite real exchange rate depreciation, exports decline sooner due to supply side losses resulting from the higher tax burden. Following a 0.2 % decline in the first period, exports recover by 2 % in the long run. The trade deficit narrows somewhat in the long run (by 2.6 %) because imports grow more slowly.

The overall increases in household and corporate incomes, private consumption, value added in the manufacturing sector and imports, cause government revenues to

increase by 1.2 % in the first period and by 2.3 % in the long run. Income, consumption, value added and imports are all taxed at various stages and thus contribute to government revenues.

It is important to look into the sectoral impacts of changes in GDP components (Table 9), as gross output in most sectors decreases in the first period, but recovers in all sectors in the long run. Expanded output also contributes to declining prices in the long run. Most of this follows the underlying trend of lower consumption (due to the increased tax burden) except in the manufacturing and construction sectors. Total investment increases in all sectors in the first period, except in the energy sector where it recovers in the short run.

Exports increase in most sectors in the first period, except in non-textile manufactured items, processed food and cotton, which see a decline in exports. Exports of non-textile manufactured items also remain below their baseline value in the short run, but do grow by 1.5 % in the long run. The negative growth in exports of public services can be explained by the fall in transport and logistics services provided by Pakistan to other countries seeking transit, in particular foreign governments seeking to access Afghanistan through Pakistan.[14]

Domestic prices decline in most sectors except for the cotton, non-textile manufacturing and energy sectors (Table 10). Since these types of goods make up a relatively larger share of the household budget among the poor, lower prices have a redistributive effect, reducing inequality.

We now look at the poverty impacts of tax-financed public infrastructure. Unlike the previous simulation, this production tax is distortionary, adversely affecting the poverty headcount in the first period through reduced consumption and income. Increased infrastructure eventually helps expand supply and lower prices, restoring consumption and investment growth and thereby improving poverty levels. In Table 11, we can see that poverty is 0.3 % lower in the long run (20 years in our microsimulation). The change in poverty is statistically significant at the 95 % confidence level.[15]

We also see in Table 12 that increased wages and proceeds from self-employment are the main drivers of poverty reduction. Constrained households see a greater reduction in their poverty levels over the long run (Table 13), as partially reflected by the higher increase in real consumption among

[14] Other items are counted under public sector services exports, transport and logistics services dominate.

[15] CGE results (regarding quantitative variables) are provided to the micro model in productive worker terms (it then takes into account the change in population, labour and technology). This approach allows us, though not fully satisfactorily, to leave the original micro-data unchanged. Then, changes in savings are introduced into the micro model by plugging in results obtained in the CGE model. Also, the macro model did not distinguish workers by skill and sector (full mobility across sectors), so the micro framework did not model the evolution in education/skills and labour mobility. Finally, for simplicity and lack of satisfactory information in the household survey, we made the hypothesis that capital endowments are fixed.

Table 9 Sectoral impacts of 4 % increase in public infrastructure investment-to-GDP ratio (tax financing), percentage change wrt base scenario

	Food crops	Minor crops	Agri Proc	Cotton	Livestock	Manufacturing	Energy	Textiles	Construction	T&C	Private services	Public services
Gross output												
First period	−0.24	0.01	−0.26	−0.26	−0.07	−0.43	−0.63	0.10	0.55	−0.09	−0.03	−0.10
Short run	0.21	0.49	0.24	0.43	0.36	0.18	−0.19	0.77	1.06	0.28	0.25	−0.11
Long run	1.22	1.35	1.32	1.89	1.34	1.61	0.89	2.06	1.98	0.98	0.82	0.05
Investment												
First period		0.58	0.10	0.62		0.06	−0.87	1.40		0.77	0.70	
Short run		1.15	0.97	1.58		1.21	0.46	1.96		1.66	1.58	
Long run		1.95	2.00	2.83		2.57	1.74	2.96		3.13	3.04	
Exports												
First period	0.05	0.44	−0.41	−0.69	0.18	−0.79		0.22		0.06	0.43	0.07
Short run	0.60	1.17	0.32	0.11	0.90	−0.15		0.93		0.47	0.44	−0.72
Long run	2.40	2.43	2.08	1.87	3.05	1.53		2.35		1.28	0.61	−1.59
Imports												
First period	−0.83	−0.92	0.14	0.89	−0.57	0.55	0.99	−0.42			−0.82	−0.39
Short run	−0.59	−1.00	0.04	1.29	−0.69	1.08	1.26	0.03			−0.09	1.03
Long run	−1.16	−0.97	−0.68	1.94	−2.01	1.83	1.30	0.76			1.18	3.06
Domestic demand												
First period	−0.25	−0.02	−0.22	−0.16	−0.07	−0.34	−0.63	0.01	0.55	−0.12	−0.03	−0.10
Short run	0.20	0.44	0.22	0.50	0.36	0.26	−0.19	0.63	1.06	0.24	0.25	−0.11
Long run	1.20	1.28	1.15	1.89	1.34	1.63	0.89	1.81	1.98	0.93	0.82	0.07
Consumption												
First period	−0.25	−0.07	−0.21	−0.14	−0.07	0.08	−0.27	−0.02	0.55	−0.12	−0.06	−0.10
Short run	0.19	0.36	0.22	0.53	0.35	0.65	0.13	0.59	1.06	0.24	0.23	0.03
Long run	1.17	1.14	1.08	1.89	1.30	1.72	0.98	1.75	1.98	0.93	0.83	0.33

Source: Authors' computation based on simulation results

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Table 10 Price impacts of 4 % increase in public infrastructure investment-to-GDP ratio (tax financing), percentage change wrt base scenario

	Food crops	Minor crops	Agri processing	Cotton	Livestock	Manufacturing	Energy	Textiles	Construction	T&C	Private services	Public services
Price of gross output												
First period	−0.32	−0.62	−15.50	−12.46	−0.12	−16.13	−34.73	5.07	0.01	−0.54	0.21	−6.54
Short run	−0.37	−0.75	−16.57	−12.48	−0.26	−16.15	−34.70	5.04	0.01	−0.56	0.34	−6.16
Long run	−0.75	−0.93	−16.76	−12.53	−0.84	−16.17	−34.67	4.94	−0.37	−0.60	0.53	−5.63
Price of domestic good												
First period	−0.15	−0.23	0.09	0.26	−0.12	0.22	0.41	−0.11	0.22	−0.09	−0.23	−0.09
Short run	−0.20	−0.36	−0.05	0.20	−0.26	0.20	0.36	−0.15	0.23	−0.11	−0.10	0.31
Long run	−0.59	−0.56	−0.45	0.01	−0.84	0.05	0.10	−0.26	−0.16	−0.17	0.10	0.84
Price of composite good												
First period	−0.09	−0.30	−0.39	−0.36	−0.03	−0.44	−0.54	−0.23	−0.10	−0.32	−0.32	−0.28
Short run	0.86	0.43	0.41	0.42	0.95	0.40	0.37	0.45	0.84	0.45	0.45	0.57
Long run	1.44	1.46	1.43	1.45	1.33	1.44	1.44	1.44	1.46	1.59	1.59	1.78
Shadow price of capital												
First period		0.24	0.14	0.25		0.13	−0.07	0.42		0.28	0.27	
Short run		0.31	0.30	0.38		0.35	0.26	0.41		0.39	0.38	
Long run		0.06	0.07	0.10		0.10	0.08	0.08		0.12	0.11	

Source: Authors' computation based on simulation results

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Table 11 Impact of 4 % increase in public infrastructure investment-to-GDP ratio on poverty headcount, as % from the base year

Simulation	1 year	5 years	20 years
International borrowing	−0.02	−0.18	−0.40[a]
Tax financing	0.012	−0.09	−0.31[a]

Source: Authors' calculation based on simulation results

[a]Indicates that the variation in comparison with the base year scenario is statistically different from zero (at 95 % confidence interval)

constrained households.[16] One could also argue on the income side (at the macro level) that the capital income of constrained households has increased relatively more than labour income. In the longer run, capital income has a greater multiplier impact on components of economic growth, implying that households are able to increase their retained savings for future consumption (or investment).[17] A related point is that prices in the most important consumption categories for constrained households decreased faster (or increased less) and their main sources of incomes increased faster (or decreased less) than non-constrained households. In terms of provincial poverty levels (Table 14), we observe a similar progress in poverty reduction as observed in the previous simulation, with Punjab, followed by Sindh, showing the largest improvement. One way to explain this is that Punjab has the largest number of constrained households which, as stated above, are simulated as having a larger increase in real consumption. The Gini inequality coefficient is higher in the first year due to the distortionary tax, then improves due to wage increases in later periods (Table 15). We may conclude that infrastructure financing through increasing production taxes is more painful in the very short term.

Finally, with respect to the contribution of the own-consumption component to poverty reductions, we found no effect. This is an expected quantitative result when the changes in self-production and/or consumer prices are sufficiently negligible. In our case it seems to be a combination of both: three of four provinces have seen reductions in self-production stocks (explained below), in addition to the small magnitude of the price change.

The report by the Sustainable Development Policy Institute entitled *Food Insecurity in Pakistan 2009* highlights that food security (including availability aspects) has deteriorated in 81 out of 131 districts of Pakistan.[18] Around 49 % of the

[16] It is important to note that we have used the classification of constrained and non-constrained households as we are interested in distinctly observing poverty and inequality effects on households with access to capital markets versus those without such access. This hypothesis is particularly pertinent in a developing country's context, where a lack of or barriers to credit access still represents a major obstacle in economic development. The constrained versus non-constrained distinction mirrors the difference in investment and savings patterns and finally results in differentiated impacts of public infrastructure investment on household welfare. In the longer term, access to financial services is expected to smooth consumption patterns.

[17] However labor income is a greater share of the overall incomes of non-constrained households.

[18] In 2003, food security conditions were deemed inadequate in 45 out of 120 districts.

Table 12 Long-run (20 years) impact of different factors on poverty headcount, as % from the base year

Variable	International borrowing	Tax financing
Wage employment	−0.25	−0.24
Self-employment	−0.20	−0.11
Consumer prices	0.06	0.04
Own-consumption	0.00	0.00
Residual	−0.01	−0.00

Source: Authors' calculation based on simulation results

Table 13 Change in poverty headcount by household type in the long-run (20 years), as % from the base year

Variable	International borrowing	Tax financing
Constrained	−0.42	−0.34
Non-constrained	−0.38	−0.27

Source: Authors' calculation based on simulation results

Table 14 Long run (20 years) poverty reduction by province, as % from the base year

Type of households	International borrowing	Tax financing
Punjab	−0.43	−0.33
Sindh	−0.40	−0.30
Khyber Pakhtunkwa	−0.35	−0.26
Balochistan	−0.33	−0.25

Source: Authors' calculation based on simulation results

Table 15 Changes in Gini inequality coefficient, as % from the base year

Simulations	1 year	5 years	20 years
International borrowing	−0.03	−0.07	−0.12
Tax financing	0.02	−0.04	−0.11

Source: Authors' calculation based on simulation results

Pakistani population does not have access to sufficient food for an active living. There is evidence of inter and intra-provincial disparities. The report also explains that, between 2003 and 2009, wheat production rose by 6 % in surplus-producing districts, but the percentage of surplus wheat available (which is usually exported) declined from 28.3 % in 2003 to 17.5 % in 2009 implying that the majority of provinces are now relying on external food sources. The above-mentioned phenomenon is also supported by the observation that wheat consumption has continued to decline because rising global crop prices effectively reduce purchasing power for wheat. In 2009 alone, wheat consumption declined by 10 %.

The report goes on to discuss at least two important implications of the high food prices and declining returns to farm activities with respect to the reduction in own-consumption. First, rising crop prices mean that the poorest farming households have squeezed their own-consumption stocks and traded them for short term monetary gains. Second (and related to first point) the coping strategy in both urban and rural areas is to meet caloric requirements from less preferred and less expensive food.

Finally, it is important to mention that in a quantitative exercise such as this one the direction of change in key macro and microeconomic variables is more important that the magnitude. While both simulations point towards greater prospects for growth and poverty reduction due to increased infrastructure investment, the choice between taxation and international financing (borrowing) will also involve difficult political considerations.

Conclusion

In this chapter we use a dynamic CGE model linked with a microsimulation model to estimate the macro–micro impact of public infrastructure investment. In the model we have made a distinction between constrained households and firms (who are constrained by their lack of access to credit and savings instruments) and non-constrained households and firms who are fully integrated into the open economy and have access to both domestic and international capital.

Two approaches to public investment are considered in our simulations. In the first case, production taxes finance the additional public infrastructure investment and foreign financing (borrowing) provides resources in the second case. Our quantitative results reveal that public infrastructure investments have the same direction of impact whether funded by taxation or international financing (borrowing), particularly when looking at the macroeconomic gains and poverty reduction. However, in the very short run (the first period, i.e., year 1), tax financing puts a strain on output in the industrial sector (because this sector faces the largest burden of taxes, particularly of production taxes) and thus reduces economic growth in the first period. However, financing from international borrowing has a certain Dutch disease-like impact in the first period, as indicated by a decline in exports. Most of our results, particularly in the real sector of the economy, are in line with earlier work by Khan and Sasaki (2001).

Real GDP grew in the longer run by 1.01 and 1.29 %, respectively under tax and international financing. Household consumption in these scenarios increased by 0.94 and 1.2 % over this time frame. In the tax financing scenario, long run increases in production make up for reduced consumption and investment in the first period. The poverty headcount ratio respectively improved by 0.31 and 0.4 % under tax financing and international borrowing. Inequality is somewhat lower in the long run in both cases.

Like with any other quantitative approach, our results should be interpreted in consideration of model limitations. Furthermore the impact of public investment not only depends on the size of investment but the efficiency with which this invested sum is utilized and absorbed. It also depends on which sectors are targeted by the government interventions. It is important not to compete with the private sector and instead only focus on areas characterized by market failure. In raising revenues through taxation, it will be important to see which sectors are taxed and in which manner(s). Achieving an increase in direct taxes will most easily be realized

if the government takes measures to remove barriers to entry and exit in the market and to remove state-designed procedures which distort consumption and production decisions.

Acknowledgements PEP is financed by the Department for International Development (DFID) of the United Kingdom (or UK Aid) and the Government of Canada through the International Development Research Center (IDRC). This particular program of research received separate funding from the Australian Agency for International Development (AusAID). We thank participants in several PEP general meetings, the 2013 GTAP annual conference in Beijing, the 2013 GDN annual conference in Manila and the 15th Sustainable Development Conference—"Sustainable Development in South Asia: Shaping the Future"—in Islamabad (2012) for helpful comments. We also salute the support and advice provided by governmental and non-governmental counterparts. Acknowledgements are also due to John Cockburn, Luca Tiberti and Yazid Dissou for technical supervision, as well as an anonymous referee for the excellent comments and inputs. Mumtaz Masud Ahmad, Ghulam Samad and Ahmed Pirzada provided support with data and background statistics on infrastructure subsectors.

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Conclusion

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The structural adjustment policies that were followed during the 1980s and 1990s have produced mixed outcomes, particularly in terms of poverty and inequality reductions. This has spurred, over the years, the international community to ask whether different combinations of public policies could have better development impacts. In particular, it is now often argued that infrastructure development can serve not only as an important source of fiscal stimulus in the short run, but also as a tool for encouraging growth in the longer run and an avenue for generating broad-based economic development. Such broad-based development is especially important since inclusiveness of growth features as an overriding objective of the current development paradigm.

It is within that context that this book seeks to understand better the role of infrastructure in fostering and broadening development. This involves considering how infrastructure investment impacts aggregate production, sectoral allocation of production, economic growth, household welfare and poverty and inequality. An encompassing and original analytical approach is used that combines the strengths of general equilibrium analysis – which is essential for taking into account the economy-wide interactions across production and consumption activities that are spurred by infrastructure policies – and the strengths of micro economic analysis – which is needed to take into account the micro level effects of major economic policies, especially in terms of household behavior, household welfare, inequality and poverty.

The book starts by presenting theoretical models of human capital and infrastructure development within an endogenous growth framework, followed by a review of some of the empirical findings on the effects of infrastructure and

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J. Cockburn et al. (eds.), *Infrastructure and Economic Growth in Asia*,
Economic Studies in Inequality, Social Exclusion and Well-Being,
DOI 10.1007/978-3-319-03137-8_6, © The Author(s) 2013

education on growth and poverty, with a particular emphasis on developing countries. Empirical evidence is then provided on the potential growth and welfare effects of increasing public investment in infrastructure in three Asian countries, the Philippines, China and Pakistan.

To provide such evidence, an intertemporal dynamic computable general equilibrium model is combined with a microsimulation model and then applied to the three countries. The total capital stock is distinguished between public and private. Consistent with the reality of developing countries, in which most households do not have access to formal credit markets, credit-constrained and credit-unconstrained households and firms are also distinguished. Unconstrained agents are characterized by their ability to take decisions on savings and investment behavior that are based partly on their expectations of the future. This is an important feature of the book's analytical framework: it recognizes that anticipations of the future (such as anticipations of the effects of infrastructure on future levels of development) can have an impact on current behavior and welfare.

Although the exact infrastructure investment amounts are country-specific, the models and types of financing mechanisms considered are common to all three countries. The differences in the macro- and micro-economic outcomes are then essentially a matter of differences in the countries' sectoral economic structure, in the distribution of assets and in production and consumption behavior.

Aggregate and sectoral production outcomes, as well as poverty and distributive impacts, are analyzed in the short, medium and long runs. These impacts are contrasted across two alternative financing mechanisms, namely distortionary (i.e., through a production tax) and non-distortionary (through international borrowing) means of financing. The overall effects of an increase in public investments in infrastructure depend on a trade-off between the increased productivity generated by such investments and the distortionary effects of taxes. These effects also depend on the productive structure of the economy considered. The structure of the economy is also important when it comes to assessing the impact on household welfare: that impact is most dependent on the initial distribution of factor endowments (and thus on the distribution of income sources) and on household preferences.

Comparisons across the three countries provide new and interesting insights. All of the evidence unambiguously suggests that increasing investment in public capital positively impacts economic growth through higher capital accumulation and greater productive capacity of private firms, both in the short and, especially, long runs. An important finding is therefore that public infrastructure investment promotes stronger growth and that the positive supply-side effects on private sector productivity increase over time. Because of this, the growth effect of public capital investment is larger in the longer term.

Initial crowding-out effects of a production tax on private sector investment are observed in all three economies, however investing in infrastructure offsets this effect over time by crowding in private investment. Public sector investment in infrastructure also generally increases aggregate household consumption, with the exception of the first-year impact in Pakistan in the specific case of financing through a production tax.

The book's results further suggest that infrastructure investment financed by international borrowing generates larger beneficial effects in Pakistan and in the Philippines, while production tax financing should be preferred in China. This result comes despite the fact that financing through international borrowing generates what is known as a Dutch disease effect of appreciation of the real exchange rate. While for Pakistan some symptoms of this disease are visible only soon after the implementation of the infrastructure policy, the Chinese and Philippine economies display signs over a longer time period. In all cases, the positive productivity effects of public capital are crucial in mitigating the Dutch disease effects on production and welfare.

The initial level of economic and infrastructure development also matters considerably. Public infrastructure investment appears to be associated with stronger long-run output and a larger crowding-in effect on the private sector in more developed economies with greater levels of private capital. This is seen inter alia when the long-term results of China are compared to those of the Philippines, two countries in which the effects of a comparable increase in public investments were simulated.

An important finding of this book's case studies is that certain industries are more sensitive to infrastructure policy than others. This is valuable policy information: some sorts of sectoral performance are more likely than others to be enhanced through investment in infrastructure. The main reason for this is that the private sector productivity impact of public capital is generally not evenly distributed across industries. Efficiency would dictate that policy should favor public infrastructure investment that is complementary to the capital of those economic sectors whose marginal product is highest in the long run.

The magnitude of the impact of public infrastructure can also differ according to the choice of financing mechanism. Public capital investment decisions should therefore take into account the type of financing mechanism associated with such decisions. The case of the Philippines is informative in this regard: investment financed through foreign borrowing produces an almost equal long-run output effect across sectors, whereas production-tax financing does not produce any effect on some sectors. Perhaps even more importantly, some sectors can gain significantly under foreign borrowing: a country can become a net exporter in such sectors, while remaining a net importer in those same sectors under a production tax.

Infrastructure investment reduces poverty significantly in all three Asian countries considered in this book. Consistent with the macroeconomic effects, all three countries show a reduction in poverty over the medium to long run following an increase in public infrastructure investment. In the short run, that is 1 year after the implementation of the infrastructure increasing policy, the poverty results are ambiguous and depend on the type of financing scheme. Under a production tax, all countries exhibit an increase in poverty. In the Philippines, this is also true under foreign borrowing, mostly due to a significant increase in consumer prices. In general, the poverty effects are larger in the long run, in line with the increased aggregate economic activity over time.

The contribution to poverty reduction made by different sectors and income sources naturally depends on the socio-economic structure of the economy being considered. This being said, it is through increased wages that infrastructure development impacts poverty most, followed by the increased self-employment revenues. Important differences are observed within each country, with rural areas generally contributing the most to the reduction of national poverty. Furthermore, both credit-constrained and credit-unconstrained households benefit from increases in public infrastructure spending, again with some differences across the countries. In the long-run, Pakistan and China see poverty fall more rapidly among credit-constrained households, while the reverse is true in the Philippines. Overall, inequality is only modestly affected by public infrastructure spending.

The final lesson is twofold. First, the analysis of broad public infrastructure strategies does benefit from an analytical framework capable of modeling the economy-wide and the time-dependent effects of such strategies. Second, the distributive impact of infrastructure strategies is naturally context-dependent: it depends on the precise infrastructure investment mechanisms that are used by the states and on their interactions with the distribution of assets, the structure of household consumption and the structure of production behavior. Both of these features are important for understanding the dual impact of infrastructure investment through economy-wide and temporal effects on consumption, production and growth, and through micro-level impacts on welfare, poverty and inequality. It is our hope that this book will have demonstrated the applicability and the usefulness of such general equilibrium and microsimulation techniques for understanding the impact of public infrastructure investment policies.