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Evidence from Europe

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Digital technologies and firm performance:
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1. Introduction and Literature

As aggregate productivity shows signs of slowing down, many hopes and fears are pinned on digital technologies. Hope is fashioned out of the notion (and evidence) that firms are more productive when they adopt new technologies. Casual observation of how digital technologies penetrate and change our daily lives encourages the seemingly safe assumption that they must have an equally transformative effect on business. Hopefully, with time (or better measurement), this will be evident in the productivity statistics too. Counteracting hope is fear - provoked by uncertainty with respect to the anticipated negative effects of digitalization on employment and market concentration.

Often these hopes and fears dwell in speculation, since the latest applications of digital technologies are iterating so quickly, empirical evidence about how they relate to socio-economic outcomes is relatively scarce. This paper uses a new dataset to contribute to a small but growing body of empirical literature that relates digital technologies to indicators of firm growth, productivity and performance.

In line with recent evidence (EIB, 2019 & 2020; Goldfarb and Tucker, 2019; Gal et al., 2019), we establish a link between digital technology adoption and performance at the firm level. Most studies that relate digital technology adoption to productivity tend to focus on a particular technology, or on generic measures of digitalization. Different studies in the literature use different units of analysis (i.e., country, sector, or firm-level). For example, several studies (Graetz and Michaels, 2018; Autor and Salomons, 2018; Dauth et al., 2017; European Commission, 2016) relate a greater presence of **industrial robotics** with increased productivity at the country level. Another subset of studies takes a sectoral perspective: Mayer (2018) finds the uptake of industrial robotics in 64 countries is related to a greater contribution of manufacturing in value-added, but not employment. Based on firm-level data from Europe, Delic et al. (2019) argue that the adoption of 3D printing (additive manufacturing) in the automotive sector improves supply chain performance (and consequently firm performance) by increasing the reliability and speed with which firms can fulfil orders.

Other studies zero-in on the firm level and report similar findings. For example, Atkinson (2018) documents a pattern of empirical evidence from numerous papers that demonstrate the positive effect of **ICT** on productivity in Europe. Using data for firms in more than a dozen European countries from 2002 to 2010, Falk and Hagsten (2015) find that e-sales are positively associated with labour productivity growth. Gal et al. (2019) use industry level adoption rates to find that greater adoption of digital technologies is positively related to greater multi-factor productivity growth for the average firm. Case studies demonstrate the potential for the Internet of Things (**IoT**) to reduce costs, creating an expected boost in profits, for firms that adopt the technology (OECD 2017).

According to recent theoretical literature, **artificial intelligence (AI)** and machine learning may have a transformative effect on how ideas and innovation are introduced into productive sectors (Cockburn et al. 2018; Aghion et al. 2019). Brynjolfsson and McAfee (2011) highlight the mechanism whereby data-driven decision-making allows greater access to information external to the firm and is therefore associated with increased productivity, especially when considering complementarities between organizational structure and IT investment (Brynjolfsson and McAfee 2011). “Aggregator” **platforms** which connect consumers to service providers may be a good example, because they help firms identify consumers’ willingness to pay, allowing the firms to tailor pricing to ‘best-matched’ sales opportunities (Li et al. 2019).

While the literature seems to be converging on the notion that digital technology adoption is positively related to productivity, empirical approaches are quite dispersed. Beyond generic ICT technologies, studies tend to focus on **one** particular digital technology (e.g. advanced robotics, 3D printing, or IoT). Distinguishing between a unique set of different digital technologies, we contend that the relationship between digital technology adoption and productivity at the firm level, may also depend - at least in part - on the technology under consideration. We note that these differences carry over into our analysis relating technology adoption to the likelihood of employment growth. Furthermore, we find evidence to support the view that there are complementarities between technologies.

Overall, our findings with respect to productivity and employment growth land on the hopeful side. Digital technology adoption tends to be significantly and positively associated with productivity. Our findings also show that digital adopters are typically not downsizing. On the contrary, they are more likely than non-digital firms to have increased the number of people they employ over the past three years (in line with EIB 2020). We also find complementarities among a wide range of advanced digital technologies – 3D printing, advanced robotics, Internet of Things and cognitive technologies such as AI and big data. Multiple technology adopters tend to be more productive than single technology adopters, with some sectoral differences. This reinforces the findings of other studies that have found complementarities between ICT; the adoption of cloud computing and high-speed broadband (DeStefano et al., 2019), or Internet and e-commerce (Forman, 2002),

2. Data and Descriptive Statistics

The main data source for our analysis is the EIB investment Survey (EIBIS) 2019. EIBIS is an annual survey with non-financial corporates conduced since 2016. Firms are asked to answer more than 50 questions with the aim to better understand the drivers and barriers of investment decisions. The survey covered 13,400 firms with at least five employees in the manufacturing, construction, services and infrastructure sector in 28 EU countries and the US. The sample is stratified by industry group (sector), size-class and country.[1] The Orbis dataset of Bureau van Dijk was used as a sampling frame in all countries.

EIBIS gathers quantitative and qualitative information on firms’ characteristics and their performance, their past and future investment activities, their source of finance, financing issues and other obstacles that hold them back from investing. The survey is based on a telephone interview. Fieldwork is carried out by the intermediary of Ipsos-MORI.

[1] The methodology of the EIBIS survey is available at: https://www.eib.org/attachments/eibis_methodology_report_2017_en.pdf .

To evaluate the current digital status of firms, we rely on the following relevant survey question from EIBIS (2019): "Can you tell me for each of the following technologies[2] if you (1) have heard about them, (2) have heard about them but not implemented, (3) implemented them in parts of your business, or (4) whether your entire business is organised around them?" Table 1 summarizes the digital technologies for the different sectors.

Table 1. State-of-the-art Digital Technologies in EIBIS (2019)

Manufacturing (NACE C)	
a)	3-D printing
b)	Automation via advanced robotics
c)	Internet of Things (IoT)
d)	Cognitive technologies such as big data analytics and artificial intelligence (AI)
Services (NACE G/I)	
a)	Augmented or virtual reality
b)	Platform technologies
c)	Internet of Things (IoT)
d)	Cognitive technologies such as big data analytics and artificial intelligence (AI)
Construction (NACE F)	
a)	3-D printing
b)	Drones
c)	Augmented or virtual reality
d)	Internet of Things (IoT)
Infrastructure (NACE D/E/H/J)	
a)	3-D printing
b)	Platform technologies
c)	Internet of Things (IoT)
d)	Cognitive technologies such as big data analytics and artificial intelligence (AI)

Source: EIBIS (2019).

A firm is labelled a **partial** adopter of a technology if it implemented that technology in parts of its business. A firm that organizes its entire business around one of the technologies is labelled a **full** adopter of that technology.[3] We label a firm a '**digital adopter**' if it is a partial or full adopter of **at least one** of the four technologies. If a firm adopted more than one of the technologies either fully or partially, it is labelled a 'multiple' adopter.

Digital adoption rates (grouping partial and full adopters together) vary by technology: 3D printing (18 percent); advanced Robotics (45 percent); IoT (35 percent); cognitive technologies such as AI and Big Data (20 percent); Platforms (37 percent); Augmented or Virtual Reality (10 percent); drones (23 percent).[4] In the analysis to follow, we chose to focus

[2] The following definitions were provided by the interviewer (IF NECESSARY): **3D printing** "also known as additive manufacturing"; **Automation via advanced robotics** "a second generation of robots, which are more autonomous, flexible and often more easily programmable"; **IoT** "electronic devices that communicate with each other without human assistance"; "Cognitive technologies such as **big data analytics and artificial intelligence**"; **Drones** "an unmanned aerial vehicle"" **Augmented or virtual reality** " presenting information integrated with real-world objects presented using a head-mounted display"; and **Platform technologies** "that connect customers with businesses or customers with other customers" (EIBIS questionnaire, 2019).

[3] Respondents who indicated (1) or (2) are grouped into 'non-digital'. Respondents who replied 'don't know' or refused are considered non-response (treated as missing).

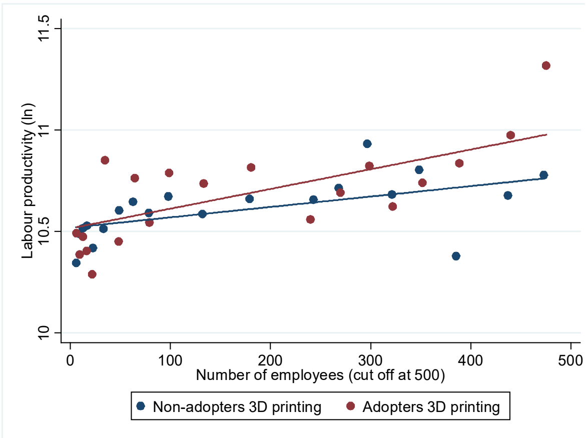
[4] Adoption rates among firms asked about augmented or virtual reality and drones were 10 and 23 percent, respectively.

on the first 5 technologies. Augmented reality is excluded because its use is least widespread. The use of drones, albeit more widespread than AI and big data or 3D printing, is excluded because its application does not relate to a variety of production processes. Digital adoption also varies considerably between the different countries in the sample, as exemplified by Figure A.3 in the Appendix which displays adoption of cognitive technologies such as Big Data and artificial intelligence by country.

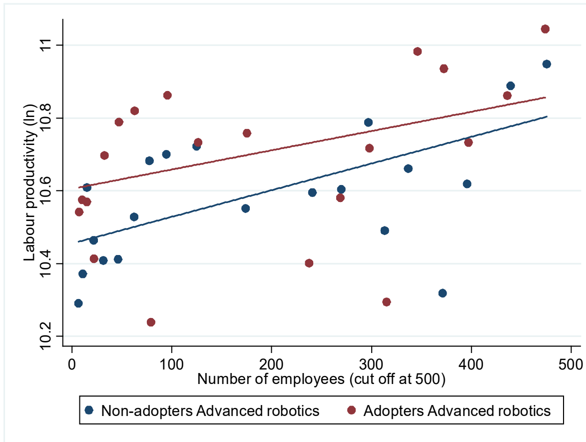
Digital technology adoption tends to be significantly and positively associated with productivity. Differences in productivity persist even if we control for firm size. The binscatter plots[5] in Figure 1 show that for nearly every firm size category, labour productivity is higher for adopters across all digital technologies. Small firms that have adopted advanced robotics appear much more productive than their non-adopting peers, but the distinction lessens as firm size increases. Whereas, for 3D printing and platform technologies, productivity differences between adopters and non-adopters seem to widen as firm size increases. The IoT and cognitive technologies seem to show relatively consistent productivity gains for adopters, across firms of different sizes.

Figure 1. Log of Labour Productivity (y-axis) by Number of Employees (x-axis), 2019

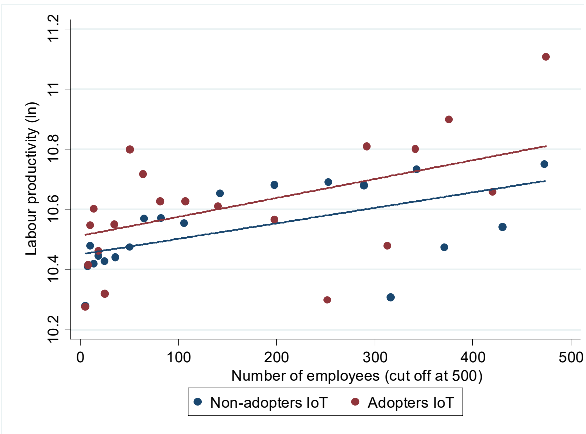
3D printing adopters vs. non-adopters



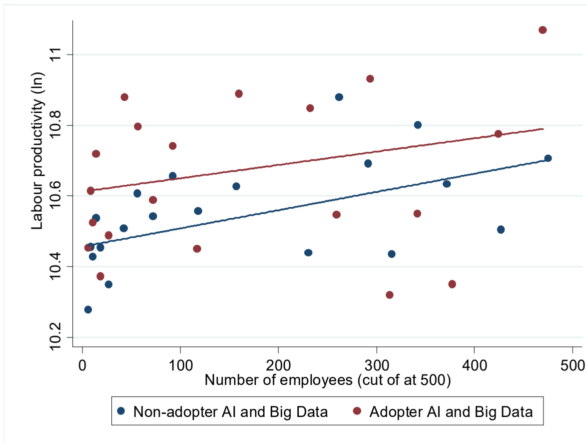
Advanced robotics adopters vs. non-adopters



Internet of Things adopters vs. non-adopters

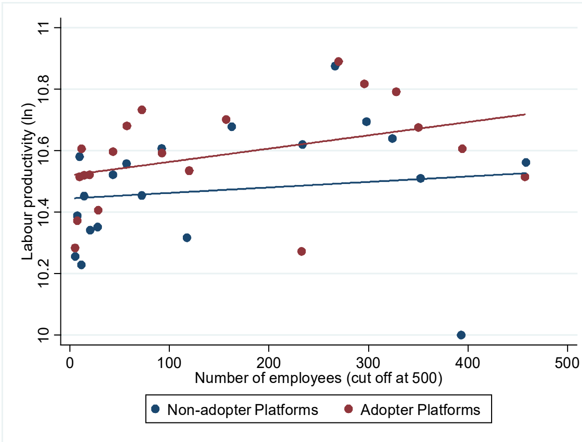


AI and Big data adopters vs. non-adopters

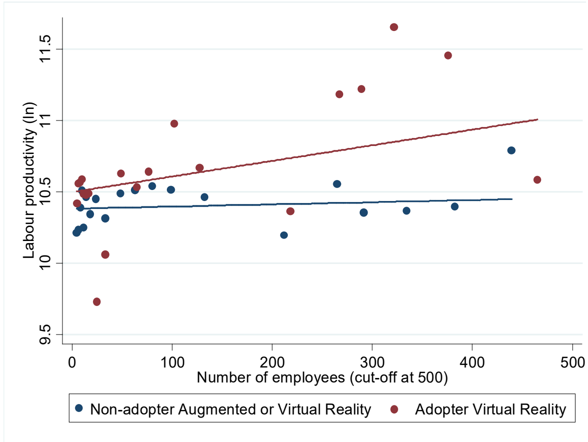


[5] The binscatter plots group the number of employees into equal-sized bins (default = 20), and then compute the means for firm size and log labor productivity within each bin and scatterplots these data points.

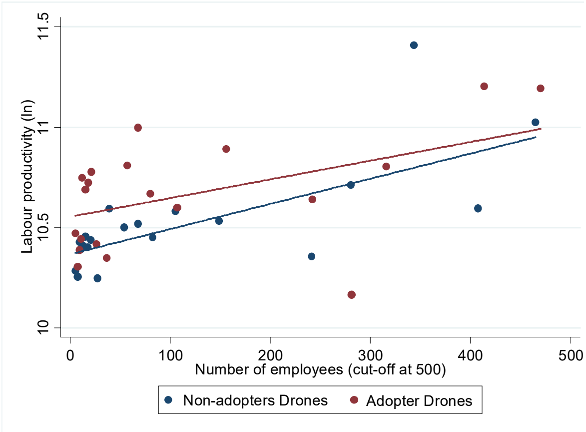
Platform adopters vs. non-adopters



Augmented/Virtual reality adopters vs non-adopters



Drone adopters vs. non-adopters



Source: Authors' calculations based on EIBIS (2019).
Note: Firms are weighted with value added. The number of employees (x-axis) is cut-off at 500, which represents around 93 percent of the sample of firms in the dataset. The descriptive results are sensitive to changes to the cut-off point.

It also appears that productivity gains associated with digital adoption is not linked to job losses. Figure A.4 in the Appendix visually summarizes how the adoption of each technology relates to each employment outcome.

3. Empirical Strategy and Results

a. Baseline specification

The following regression model is estimated using OLS to assess association between digital adoption and labour productivity. The dependent variable is the log of labour productivity (a firm's value-added divided by its number of employees). Country-specific and sector-specific effects are controlled for. Sector is a categorical variable, and the reference sector in this regression is always indicated. The model is specified as follows:

$$Log\ of\ Labor\ Productivity = \alpha + \beta_1 Digital\ technology\ adoption + \beta_2 Sector + \delta \text{Country} + \mu$$

We find that digital technology adoption is positively related to productivity at the firm level, but the significance of the coefficient differs by technology (Table 2).

Table 2. Baseline OLS Regressions relating Technology Adoption and Labour Productivity

Dependent Variable: Log of Labour Productivity						
	3D Printing	Advanced Robotics	IoT	AI / Big Data Analytics	Platforms	Digital Adoption
Digital Technology	**0.11**** (0.05)	**0.13**** (0.06)	**0.03** (0.04)	**0.09*** (0.05)	**0.09*** (0.06)	**0.11***** (0.03)
Sector						
Manufacturing	Reference	**Only Sector**	Reference	Reference	N/A	Reference
Construction	-0.03 (0.04)	N/A	-0.04 (0.04)	N/A	N/A	-0.01 (0.04)
Services	N/A	N/A	-0.32*** (0.04)	-0.33*** (0.04)	Reference	-0.31*** (0.05)
Infrastructure	0.04 (0.04)	N/A	0.03 (0.04)	0.02 (0.04)	0.35*** (0.05)	0.05 (0.04)
Country dummies	yes	yes	yes	yes	yes	Yes
N	7713	3157	10192	8084	4932	10309
Adjusted R-Squared	0.19	0.24	0.17	0.17	0.15	0.17

Source: Authors' calculations based on EIBIS (2019).
Notes: The constant and country dummies are included, but not reported. Firms in different sectors were asked about different digital technologies. N/A indicates when a sector was not asked about a particular technology. The reference sector is also indicated. **Specific technology adoption does not exclude the possibility of adopting one of the other technologies as well.** Firms in EIBIS are weighted with value added. All countries in the EU28 and the United States are included in the regressions. Robust standard errors in parentheses. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

IoT is the only technology surveyed in every sector. While the results for the different technologies are presented side-by-side, they should be interpreted cautiously. A direct comparison can only be made between IoT and digital adoption. The coefficient on digital adoption is positive and statistically significant at the 1 percent level. Comparing the adoption of IoT with the broader measure of digital adoption suggests that the link to productivity differs by technology. It is also the first clue that multiple technology adoption may have a stronger relationship with firm level productivity than single technology adoption. While the adoption of each technology presented in Table 2 does not exclude the possibility of adopting another technology, the variable indicates at least partial adoption of that particular technology.

b. Robustness checks

There are many firm-level characteristics that matter for digital adoption but may also impact labour productivity independently. Firm size, firm age, exporter status, and innovation preparedness are all mitigating factors that can influence the relationship between digital adoption and firm productivity. These variables are observed in the data under consideration and therefore be controlled for in the regression equation.

Despite controlling for these firm-level characteristics, there may be unobservables, which are correlated with both firm productivity and digital adoption. This could result in biased estimates. Furthermore, there are concerns of reverse causality, especially given the lack of time variation in the data under consideration. It cannot be established whether firms are more productive because they adopted digital technologies, or they adopted digital technologies because they were more productive. We therefore estimate an instrument variable specification where digital adoption at the firm level is instrumented with the share of digital adopters (for each technology, digital adopters and multiple adopters) in the same country-sector-productivity quintile. The prevalence of digital adoption in firms in the same country, sector, and productivity quintile should be exogenous to the individual firm's labour productivity. Even though we may not completely circumvent the endogeneity issue, we do consider this a robustness check. It lends credence to our claim that digital adoption is positively and significantly related to labour productivity.

This IV specification estimates the following equation:

$$\begin{aligned} Log\ of\ Labor\ Productivity \\ &= \alpha + \beta_1 Digital\ technology\ adoption\ + \beta_2 Sector + \beta_3 Size\ \ + \beta_4 Age \\ &+ \beta_5 Exporter + \delta Country\ + \mu \end{aligned}$$

Instrumental variable regression results are presented in Appendix 3. The digital adoption of each technology has a positive effect on labour productivity. The adoption of multiple digital technologies also has a positive effect on labour productivity. Multiple digital technology adoption is an ordered discrete variable that takes a value of 0 if the firm did not adopt any digital technology, a value of 1 if it has adopted only one digital technology, and a value of 2 if the firm has adopter two or more digital technologies.

c. *Channel: are labour productivity gains associated with job losses?*

Since our measure of productivity is value-added per employee, it is important to verify that the positive relationship between digital adoption and productivity is not necessarily based on a shrinking denominator. The EIBIS asked firms about the number of employees in 2019 and about the number of employees 3 years before. It is thus possible to identify firms that report employment growth, employment stability, and firms that downsized. We estimate binary logistic regressions to assess whether digital technology adoption is a significant predictor of the likelihood of increased employment over the past 3 years, while the base is either employment stability or downsizing. The model can be specified as follows

$$\begin{aligned} Increase\ in\ employment\ over\ past\ 3\ years \\ &= \mathrm{G}(\beta_1 Digital\ technology\ adoption\ + \beta_2 Sector + \beta_3 Size\ \ + \beta_4 Age \\ &+ \beta_5 Exporter + \beta_6 Innovation + \delta Country\ + \mu) \end{aligned}$$

The logistic regressions results presented in Table 3 show that (controlling for country and sector differences): Internet of Things (IoT), cognitive technologies such as AI and Big Data and platforms are significant predictors of the likelihood of employment growth in firms over the past 3 years. On the other hand, 3D printing and Advanced Robotics are not significant predictors of employment growth in firms over the past 3 years. None of the digital technologies analysed here appear to be costing jobs, but there are differences between technologies and the likelihood that adoption predicts employment growth. In fact, with IoT in particular, it may be that growth in employment (the denominator in our productivity variable) partially obscures the relationship between the technology and labour productivity at the firm level. These results support recent theories (Acemoglu and Restrepo 2018; Autor and Salomons 2017) that technological displacement is more likely to affect particular tasks than whole jobs and may be offset by the creation of new tasks and new jobs.

Table 3. Logistic Regressions relating Technology Adoption to Employment Growth

	Dependent Variable Logit: Increase in employment compared to 3 years ago = 1, and otherwise = 0																	
	3D Printing			Robotics			IoT			AI & Big Data			Platforms			Digital Adoption		
Digital Adoption	0.13	-0.06	0.05	0.12	-0.04	0.15	0.51***	0.42***	0.34***	0.31***	0.15	0.27*	0.32***	0.14	0.11	0.49***	0.29***	0.34***
	(0.14)	(0.15)	(0.17)	(0.15)	(0.17)	(0.18)	0.09)	(0.09)	(0.1)	(0.12)	(0.13)	(0.15)	(0.11)	(0.12)	(0.14)	(0.08)	(0.09)	(0.1)
Sector																		
Manufacturing		*Reference*			*Only Sector*			*Reference*			*Reference*						*Reference*	
Construction	0.06	0.38***	0.42***				0.1	0.40***	0.44***							0.17	0.42***	0.45***
	(0.11)	(0.13)	(0.15)				(0.11)	(0.13)	(0.15)							(0.11)	(0.13)	(0.15)
Services	N/A	N/A	N/A				-0.23**	0.02	0.19	-0.24**	0.03	0.19		*Reference*		-0.17*	0.05	0.19
							(0.1)	(0.12)	(0.13)	(0.11)	(0.12)	(0.14)				(0.1)	(0.12)	(0.13)
Infrastructure	-0.02	0.15	0.17				-0.03	0.16	0.14	-0.07	0.15	0.12	0.20*	0.14	-0.07	-0.02	0.15	0.14
	(0.1)	(0.12)	(0.13)				(0.1)	(0.12)	(0.13)	(0.1)	(0.12)	(0.13)	(0.11)	(0.12)	(0.14)	('0.1)	(0.12)	(0.13)
Firm Size																		
Micro		*Reference*			*Reference*			*Reference*			*Reference*			*Reference*			*Reference*	
Small		0.79***	0.73***		0.73***	0.49*		0.84***	0.85***		0.78***	0.79***		0.81***	0.86***		0.83***	0.84***
		(0.12)	(0.14)		(0.21)	(0.26)		(0.09)	(0.11)		(0.1)	(0.12)		(0.12)	(0.14)		(0.09)	(0.11)
Medium		1.09***	1.00***		1.13***	0.82***		1.08***	1.04***		1.04***	0.97***		1.02***	1.01***		1.08***	1.03***
		(0.12)	(0.15)		(0.23)(	(0.27)		(0.1)	(0.12)		(0.11)	(0.13)		(0.13)	(0.16)		(0.1)	(0.12)
Large		1.19***	1.00***		0.95***	0.59*		1.15***	1.10***		1.11***	1.02***		1.23***	1.25***		1.13***	1.06***
		(0.14)	(0.17)		(0.25)	(0.3)		(0.11)	(0.14)		(0.12)	(0.15)		(0.15)	(0.18)		(0.11)	(0.14)
Firm Age																		
Less than 5 years		*Reference*			*Reference*			*Reference*			*Reference*			*Reference*			*Reference*	
5 years to less than 10 years		0.04	-0.38		-0.08	-0.29		-0.1	-0.41		-0.16	-0.49		-0.18	-0.49		-0.15	-0.41
		(0.36)	(0.36)		(0.49)	(0.56)		(0.28)	(0.29)		(0.31)	(0.32)		(0.39)	(0.38)		(0.28)	(0.29)
10 years to less than 20 years		0.16	-0.11		-0.18	-0.1		0.04	-0.12		0.01	-0.08		0.12	-0.04		-0.03	-0.13

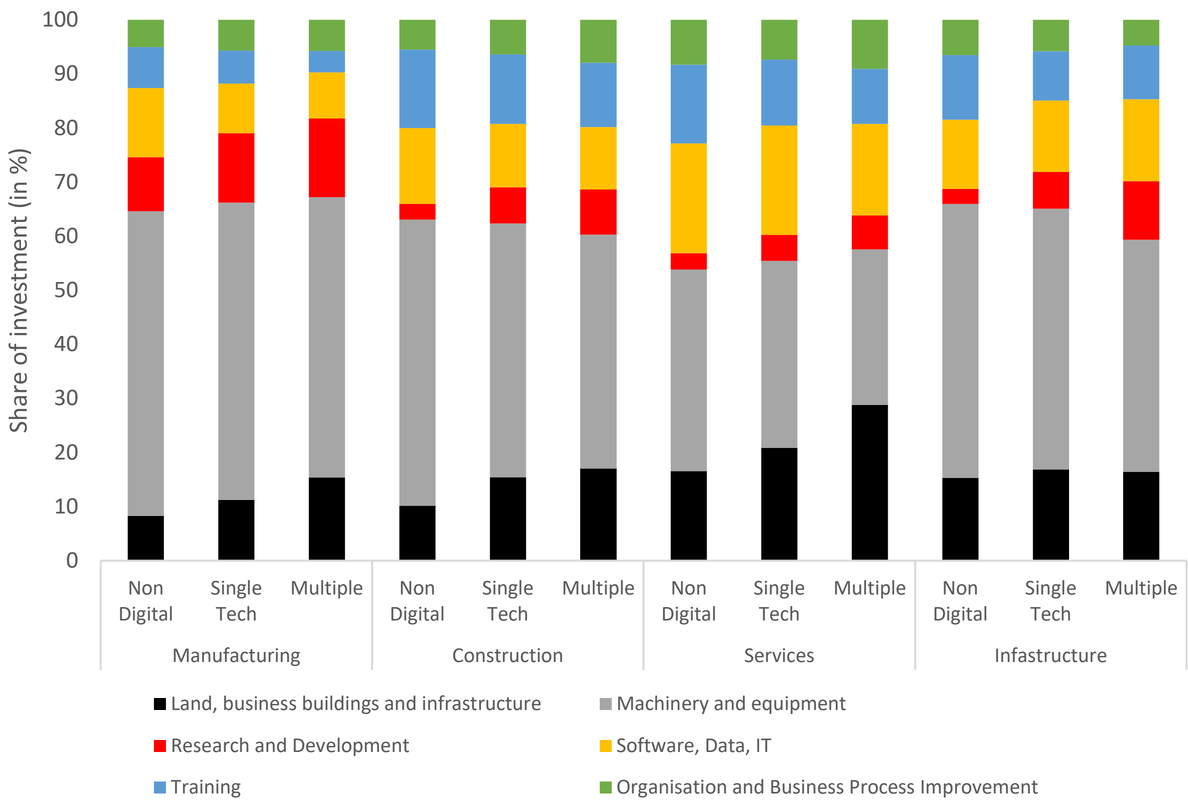
		(0.33)	(0.32)		(0.46)	(0.52)		(0.25)	(0.25)		(0.28)	(0.28)		(0.36)	(0.31)		(0.26)	(0.25)
20 years or more		-0.28	-0.55*		-0.42	-0.54		-0.34	-0.51**		-0.4	-0.54**		-0.36	-0.49		-0.42*	-0.52**
		(0.32)	(0.31)		(0.42)	(0.48)		(0.24)	(0.23)		(0.27)	(0.26)		(0.35)	(0.3)		(0.25)	(0.24)
Exporter		0.25**	0.29**		0.13	0.18		0.21**	0.26**		0.26**	0.30**		0.27**	0.35**		0.20**	0.25**
		(0.12)	(0.13)		(0.21)	(0.24)		(0.1)	(0.11)		(0.1)	(0.12)		(0.12)	(0.14)		(0.1)	(0.11)
Innovator		0.41***			0.41***			0.37***			0.36***			0.38***			0.36***	
		(0.11)			(0.16)			(0.09)			(0.1)			(0.13)			(0.09)	
Innovation Profile																		
Basic			*Reference*			*Reference*			*Reference*			*Reference*			*Reference*			*Reference*
Adopting			0.14			0.36			0.18			0.23			0.17			0.15
			(0.22)			(0.35)			(0.19)			(0.2)			(0.25)			(0.19)
Incremental innovators			0.61***			0.77***			0.50***			0.52***			0.43**			0.48***
			(0.17)			(0.25)			(0.14)			(0.15)			(0.19)			(0.14)
Leading innovators			0.35*			0.33			0.34*			0.32*			0.55**			0.26
			(0.2)			(0.28)			(0.18)			(0.19)			(0.26)			(0.18)
Developers			0.34**			0.36			0.32**			0.35**			0.43**			0.30**
			(6814)			(0.25)			(0.13)			(.14)			(0.18)			(0.13)
N	9183	8915	6814	3704	3613	2818	12216	11837	8946	9702	9400	7121	6003	5786	4306	12380	11997	9037
pseudo r2	0.01	0.04	0.03	0.03	0.05	0.07	0.02	0.04	0.04	0.01	0.04	0.03	0.01	0.04	0.04	0.02	0.04	0.04

Source: Authors' calculations based on EIB (2019).

Notes: The constant and country dummies are included, but not reported. Firms in different sectors were asked about different digital technologies. N/A indicates when a sector was not asked about a particular technology. The reference sector is also indicated. Specific technology adoption does not exclude the possibility of adopting one of the other technologies as well. Innovation Profiles are based on Veugelers et al. (2019) and defined as follows: Basic firms conduct no R&D and introduced no innovation; Adopting: no R&D, but introduced 'new to firm' innovation; Incremental innovators: R&D investors and 'new to firm or country' innovators; Leading innovators: R&D investors and 'new to world' innovators; and Developers: R&D investors with no recent innovation. Firms in EIBIS are weighted with value added. All countries in the EU28 and the United States are included in the regressions. Robust standard errors in parentheses. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

Our data allow us to observe firms' investment patterns and their reported obstacles to investment. From the information summarized in Figure 2, within sectors, the multiple technology adopters tend to invest more in research and development and less in machinery and equipment, than single technology adopters or non-digital firms. The stronger focus is particularly pronounced in the manufacturing sector. Despite more investment in R&D and a lower share in machinery and equipment, we do not find a decline in firms' investment intensity defined as investment over turnover. In fact, we consistently find a higher investment spend among multiple adopters than non-digital or single technology firms. This is true even if we zoom into sector classes.

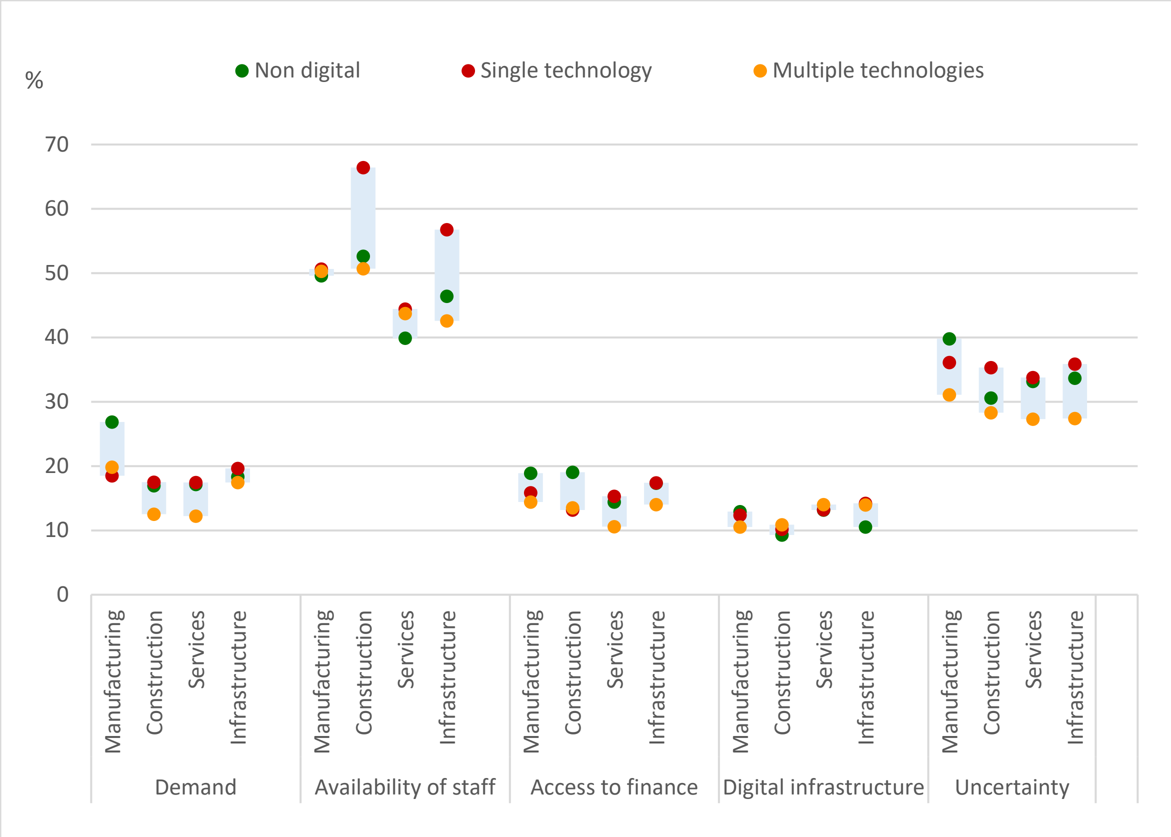
Figure 2. Allocation of Investment by Sector and Digital Intensity, 2019



Source: Authors' calculations based on EIB (2019).
Note: Firms are weighted with value added. Multiple digital technology adoption is an ordered discrete variable that takes a value of 0 if the firm did not adopt any digital technology, a value of 1 if it has adopted only one digital technology, and a value of 2 if the firm has adopter two or more digital technologies.

The most ubiquitously cited obstacle to investment is the availability of staff with the right skills, regardless of digital intensity (non-digital, single or multiple technology adopter). In the construction and infrastructure sectors, it is the single technology adopters that claim skill shortages as the major obstacle to investment. It may be that they perceive the potential economic benefit to multiple technology adoption, but need to grow their capabilities before investing in becoming more digital.

Figure 3. Major obstacles to Investment by Sector and Digital Intensity, 2019



Source: Authors' calculations based on EIB (2019).
Note: Firms are weighted with value added. Multiple digital technology adoption is an ordered discrete variable that takes a value of 0 if the firm did not adopt any digital technology, a value of 1 if it has adopted only one digital technology, and a value of 2 if the firm has adopter two or more digital technologies.

4. Conclusions

Artificial intelligence, 3D printers, machines that communicate with no human interference (Internet of Things), digital platforms, and advanced robotics are real and increasingly prevalent in all walks of life and work. They provoke fascination and fear. The lure of technological trajectories inspires hopeful visions of their potential to boost economic growth. Fear of the unknown dampens the fantasy. The potential downside of anticipated effects on employment and inequality, lurks in the background. In this paper, we made use of new EIBIS data with information about a unique set of digital technologies. We observe that these digital technologies tend to enhance firm productivity without displacing labour, but there are differences (and maybe complementarities) between technologies.

Our results essentially support previous evidence from the literature, which argues that digital technologies increase the bounty. Policy makers need to worry about the spread of the bounty; and individual people need to equip themselves with skills to learn to work with machines and maybe even to learn from them.

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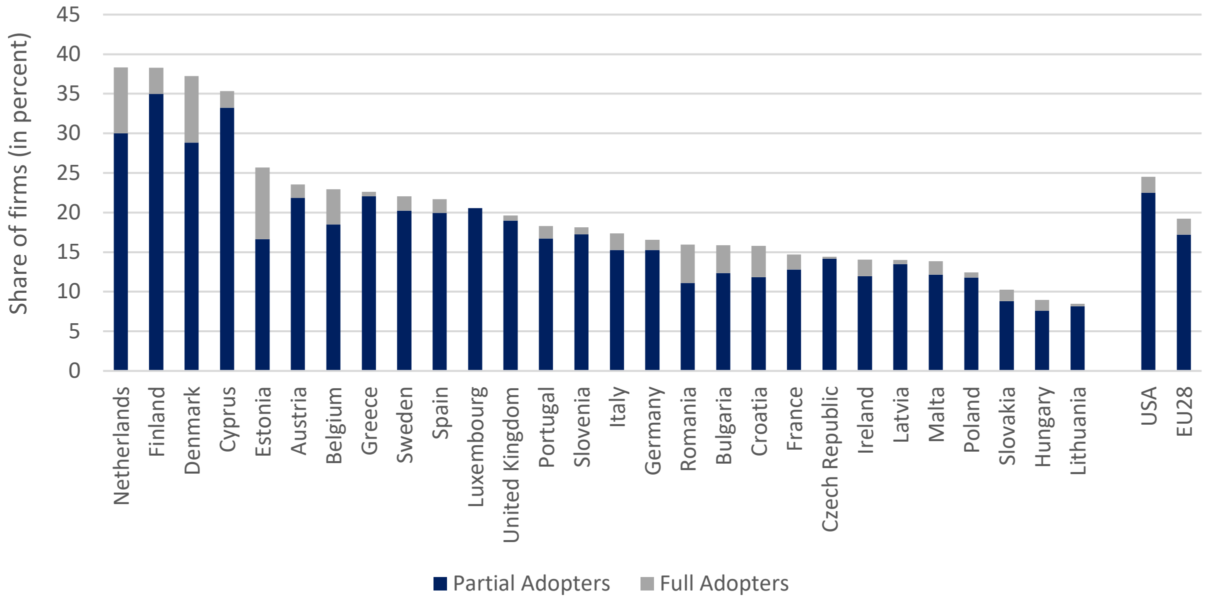
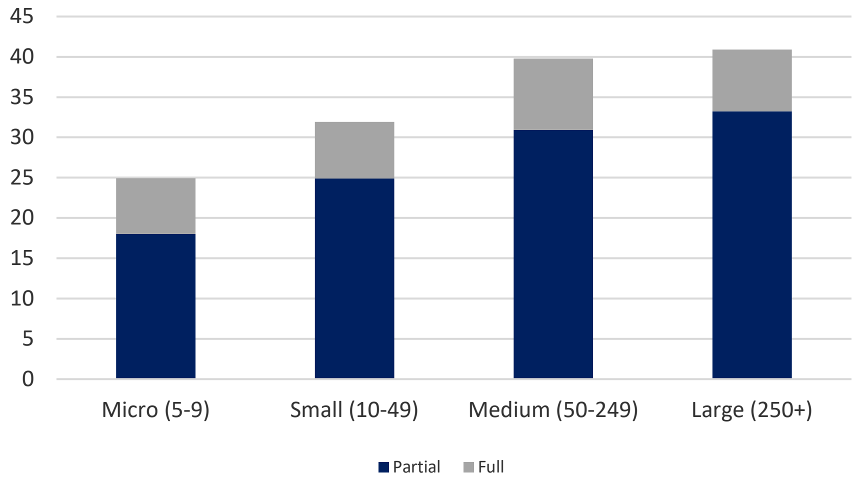
Appendix

Figure A.1. Share of firms that report having partially or fully adopted cognitive technologies such as AI and big data analytics, 2019



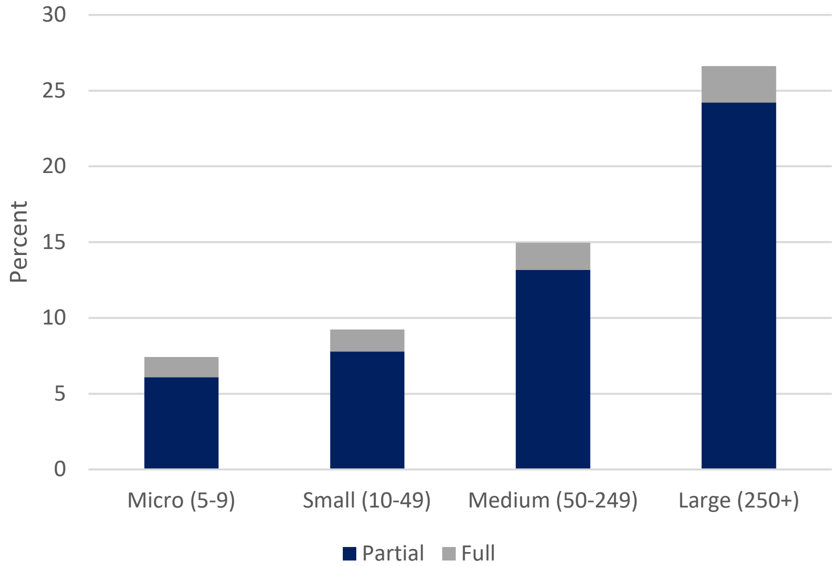
Source: Authors' calculations based on EIBIS (2019).

Figure A.2: The share of firms using digital platforms in the EU by Firm Size (in percent), 2019



Source: Authors' calculations based on EIBIS (2019).

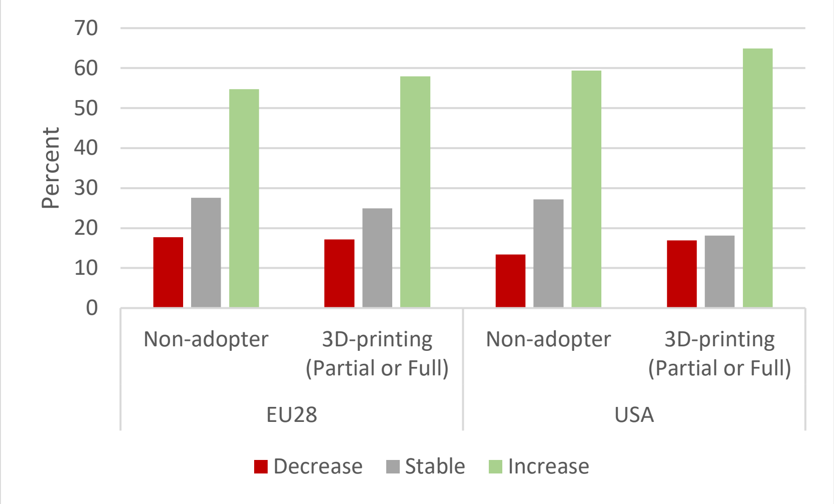
Figure A.3 Share of firms using cognitive technologies such as AI and big data analytics, 2019



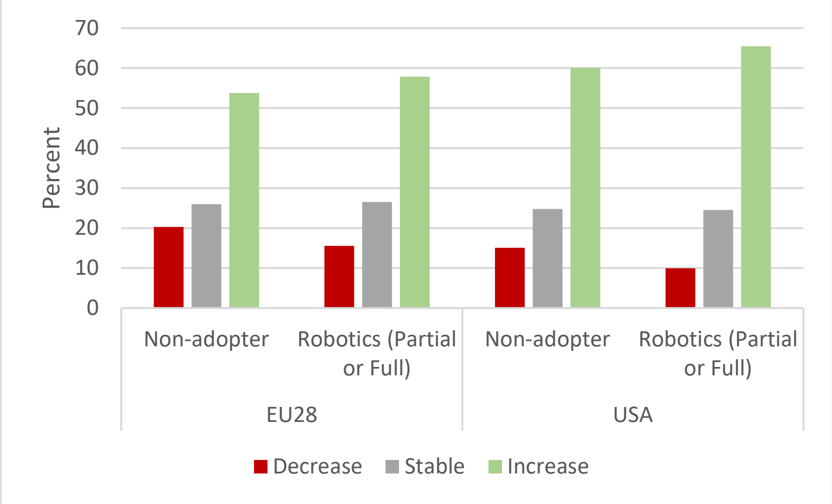
Source: Authors' calculations based on EIBIS (2019).

Figure A.4: Trends in employment growth over the past three years, by digital adoption, 2019

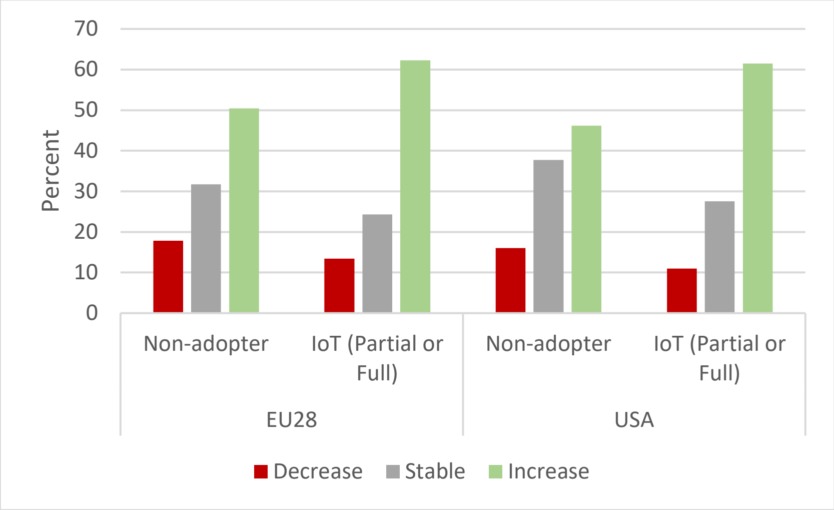
3D printing



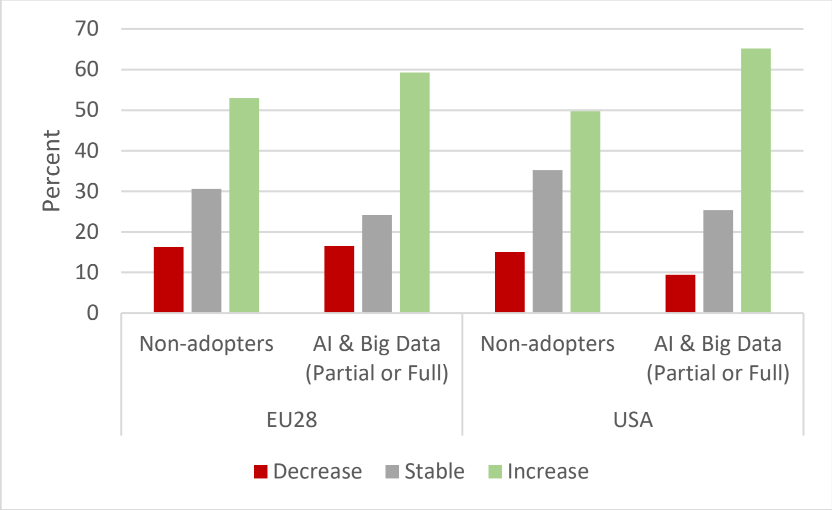
Advanced robotics



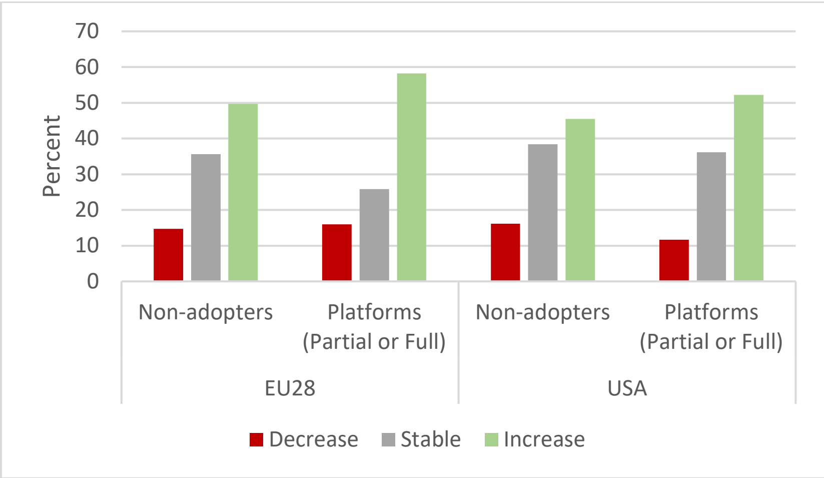
Internet of Things (IoT)



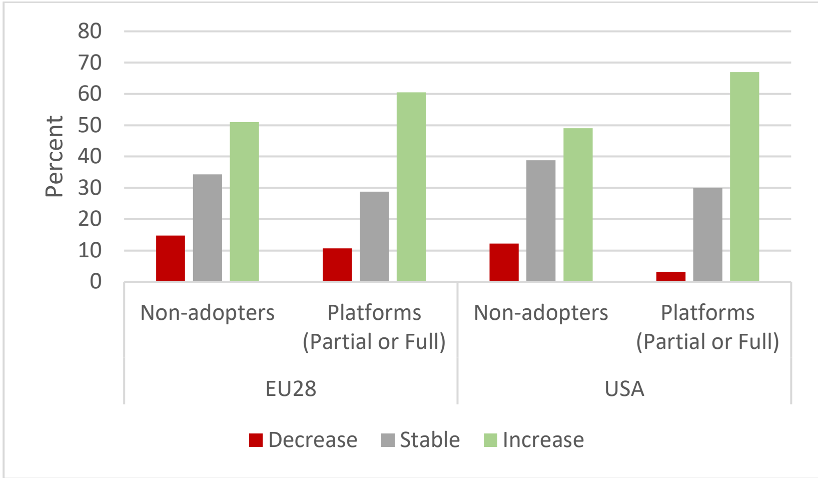
AI and big data analytics



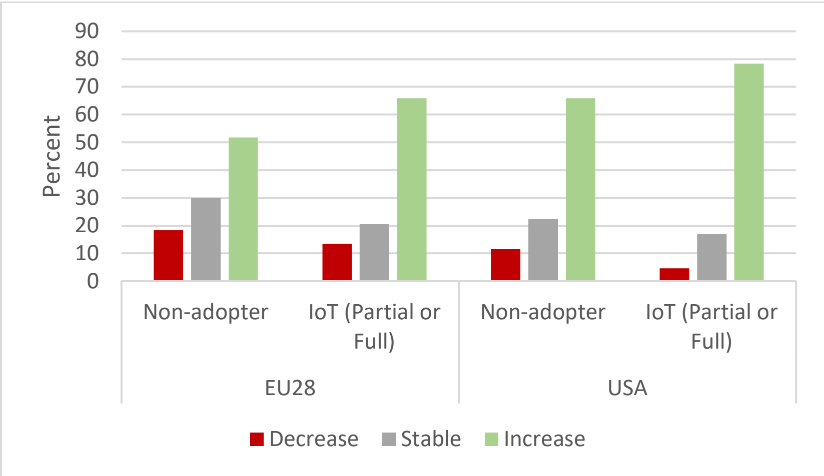
Digital platforms



Augmented and virtual reality



Drones



Source: Authors' calculations based on EIBIS (2019).
Note: Firms are weighted with value added.

Table A.1. Instrumental Variable Regressions relating Technology Adoption and Labour Productivity

	Dependent Variable: Log of Labour Productivity											
	Digital Adopt	Multi	3D Printing Only	3D Printing Adopt	IoT Only	IoT Adopter	AI / Big Data Only	AI/ Big Data Adopter	Platform Only	Platform Adopter	Robotics Only	Robotics Adopter
Technology Adoption	2.28***	0.71***	1.37**	1.25***	0.63**	1.28***	1.67***	1.97***	1.23***	1.51***	1.62***	2.94***
	(0.25)	(0.23)	(0.69)	(0.36)	(0.26)	(0.20)	(0.51)	(0.32)	(0.39)	(0.28)	(0.41)	(0.64)
Manufacturing	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference			Only	Only
Construction	0.42***	0.31***	0.17**	0.24***	0.12**	0.23***						
	(0.09)	(0.08)	(0.07)	(0.08)	(0.06)	(0.06)						
Services	-0.11	-0.20***			-0.16***	-0.20***	-0.17***	-0.26***	0.00	0.00		
	(0.08)	(0.07)			(0.06)	(0.06)	(0.05)	(0.07)	(.)	(.)		
Infrastructure	0.14*	0.17**	0.26***	0.34***	0.22***	0.15**	0.13**	-0.07	0.33***	0.27***		
	(0.08)	(0.07)	(0.07)	(0.09)	(0.06)	(0.06)	(0.05)	(0.08)	(0.06)	(0.07)		
Firm Size and Age controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Exporter status	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	Yes
N	10285	5494	7008	7693	8129	10168	7022	8065	3710	4917	2447	3153

Source: Authors' calculations based on EIBIS (2019).

Notes: The constant and country dummies are included, but not reported. Firms in different sectors were asked about different digital technologies. The reference sector is indicated. Technology adoption does not exclude the possibility of adopting one of the other technologies as well. In the columns where 'only' is specified, it means that the particular technology and no other technology in the survey was adopted. Firms in EIBIS are weighted with value added. Robust standard errors in parentheses. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

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