Online Appendix for "Digitalization and Productivity: In Search of the Holy Grail Firm-level Empirical Evidence from European Countries"

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1 The main article is available at http://www.csls.ca/ipm/37/OECD.pdf.

Appendix A. Description of the data and variables used

Table A1: Description of variables and sources

	Description	Coverage	Dimension used in analysis	Source	Link
Digital Technologies					
High-speed Broadband	Maximum contracted download speed of the fastest internet connection is at least 30 Mb/s (e_ispdf_ge30)	2014-2016	Sector, Country	Eurostat - Digital economy and society statistics - households and individuals	http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensive-database
CC	Buy cloud computing services used over the internet (E_CC)	2014-2016	Sector, Country	Eurostat - Digital economy and society statistics - households and individuals	http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensive-database
ERP	Enterprises who have ERP software package to share information between different functional areas (E_ERP1)	2010; 2012-15	Sector, Country, (Time)	Eurostat - Digital economy and society statistics - households and individuals	http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensive-database
CRM	Enterprises using software solutions like Customer Relationship Management (CRM)	2010; 2014-2015	Sector, Country	Eurostat - Digital economy and society statistics - households and individuals	http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensive-database
CC complex	Buy high CC services (accounting software applications, CRM software, computing power)(E_CC_HI)	2014-2016	Sector, Country	Eurostat - Digital economy and society statistics - households and individuals	http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensive-database
SCM	Automatic linking of enterprises to their suppliers and/or customers application	2010-15	Sector, Country, Time	Eurostat - Digital economy and society statistics - households and individuals http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensive-database	
Firm-level variables					
Frontier growth	Average growth of the top 5 percent firms in each sector-year cell	2009-2015	Sector, Time	ORBIS, based on Bureau van Dijk (BvD)	N.A.
Gap to frontier	Firms' lagged distance to the frontier	2009-2015	Firm, Sector, Country, Time	ORBIS, based on Bureau van Dijk (BvD)	N.A.
Age	Firms' age	2009-2015	Firm, Sector, Country, Time	ORBIS, based on Bureau van Dijk (BvD)	N.A.
Employees	Firms' number of employees (log)	2009-2015	Firm, Sector, Country, Time	ORBIS, based on Bureau van Dijk (BvD)	N.A.
Intangibles	Stock of intangible capital (log)	2009-2015	Firm, Sector, Country, Time	ORBIS, based on Bureau van Dijk (BvD)	N.A.
Capex	Capital expenditures (log)	2009-2015	Firm, Sector, Country, Time	ORBIS, based on Bureau van Dijk (BvD)	N.A.
Other					
Routine tasks	Routine content intensity (US)	2010-15	Sector	Marcolin et al. (2016), based on the OECD Programme for the International Assessment of Adult Competencies (PIAAC) and European Labour Force Survey (1995-2015).	
Knowledge Intensity	Share of labour compensation of personnel with tertiary education (US)	1995-2000	Sector	OECD (2013)	http://dx.doi.org/10.1787/9789264193307-en
Occupational shortages	General skill shortage	2011-15	Sector, Country	OECD, 2018	http://dx.doi.org/10.1787/9789264277878-en.
Resource management skills	Ability to allocate resources efficiently	2011-15	Sector, Country	OECD, 2018	http://dx.doi.org/10.1787/9789264277878-en.
Management of personnel resources	Ability of managers to motivate, develop and direct people as they work, and identify the best people for each job	2011-15	Sector, Country	OECD, 2018	http://dx.doi.org/10.1787/9789264277878-en.
Computer and electronics	Knowledge of circuit boards, processors, chips, electronic equipment, computer hardware and software, including application and programming	2011-15	Sector, Country	OECD, 2018	http://dx.doi.org/10.1787/9789264277878-en.
Technical skills	Worker's capacity to design, set-up, operate and correct malfunctions, involving application of machines or technological systems	2011-15	Sector, Country	OECD, 2018	http://dx.doi.org/10.1787/9789264277878-en.

Table A2: Country coverage

Austria	Belgium	Denmark	Estonia	Finland
France	Germany	Greece	Hungary	Ireland
Italy	Latvia	Netherlands	Poland	Portugal
Slovenia	Spain	Sweden	Turkey	United Kingdom

Table A3: Average adoption rates by sector (2010-2016)

NACE Rev 2	Description	ERP	CRM	CC	CC (complex)
10-12	Manufacture of beverages, food and tobacco products	0.271245	0.188223	0.179248	0.099456
13-15	Manufacture of textiles, wearing apparel, leather and related products	0.308204	0.212234	0.181328	0.084579
16-18	Manufacture of wood & products of wood & cork, except furniture; articles of straw & plaiting materials; paper & paper products; printing & reproduction of recorded media	0.291412	0.26719	0.188538	0.090067
19-23	Manufacture of coke, refined petroleum, chemical & basic pharmaceutical products, rubber & plastics, other non-metallic mineral products	0.42955	0.326845	0.227648	0.112065
24-25	Manufacture of basic metals & fabricated metal products excluding machines & equipments	0.333373	0.248728	0.178942	0.080149
26	Manufacture of computer, electronic and optical products	0.556172	0.447013	0.278731	0.147594
27-28	Manufacture of electrical equipment, machinery and equipment n.e.c.	0.455789	0.352506	0.187869	0.086747
29-30	Manufacture of motor vehicles, trailers and semi-trailers, other transport equipment	0.501986	0.276797	0.212032	0.095408
31-33	Manufacture of furniture and other manufacturing; repair and installation of machinery and equipment	0.272652	0.228846	0.191396	0.094772
35_39	Electricity, gas, steam, air conditioning and water supply	0.341647	0.32225	0.259049	0.133773
41_43	Construction	0.156103	0.144789	0.199024	0.112612
45	Trade of motor vehicles and motorcycles	0.301579	0.427382	0.182405	0.115079
46	Wholesale trade, except of motor vehicles and motorcycles	0.402495	0.393588	0.235896	0.130059
47	Retail trade, except of motor vehicles and motorcycles	0.22922	0.238353	0.177975	0.103962
49_53	Transportation and storage	0.198024	0.203841	0.195679	0.103173
55_56	Accommodation and Food and beverage service activities	0.111989	0.16216	0.165641	0.104095
58-60	Publishing activities; motion picture, video & television programme production, sound recording & music publishing; programming & broadcasting	0.330037	0.42285	0.385612	0.247627
61	Telecommunications	0.480137	0.659599	0.389523	0.254364
62-63	Computer programming, consultancy and related activities, information service activities	0.445565	0.605442	0.555143	0.402173
68	Real estate activities	0.225138	0.284749	0.256101	0.153134
69-74	Professional, scientific and technical activities	0.256945	0.333358	0.337497	0.203696
77-82	Administrative and support service activities	0.199038	0.279514	0.250756	0.161046

This table reports average adoption rates across industries for a set of 20 countries over the time period 2010-2016 (depending on data availability).
Source: based on Eurostat, Digital Economy and Society (database), http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensivedatabase (accessed September 2017).

Table A4: Correlations across digital technologies

	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)
High-speed broadband	1				
Enterprise Resource Planning	0.152***	1			
Customer Relationship Management	0.3252***	0.5318***	1		
Cloud Computing	0.2312***	0.0744***	0.4108***	1	
Cloud Computing (complex)	0.1331***	0.0791***	0.4582***	0.762***	1

Note: ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively. Estimates are purged of country and industry fixed effects.

Table A5: Principal Component Analysis

Panel A: Eigenvalue

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	3.05223	1.93051	0.6104	0.6104
Comp2	1.12172	0.547131	0.2243	0.8348
Comp3	0.574586	0.375566	0.1149	0.9497
Comp4	0.19902	0.146568	0.0398	0.9895
Comp5	0.0524514	.	0.0105	1

Panel B: Eigenvector

	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)
1st principal component	0.4207	0.3088	0.4816	0.4917	0.5039

Table A6: The correlation between skill shortages and digital adoption

	Computer skills	Technical skills	Management of Personnel Resources	Resource Management skills
High-speed broadband	0.0645***	0.079***	0.0894***	0.0932***
Enterprise Resource Planning	-0.0807***	-0.0918**	-0.0602***	-0.0557***
Customer Relationship Management	-0.0484***	-0.0399***	-0.04***	-0.036***
Cloud Computing	0.0529***	0.0555***	0.0413***	0.0415***
Cloud Computing (complex)	0.0097***	-0.0096***	-0.023**	-0.0208***

Note: ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively. Estimates are purged of country and industry fixed effects.

Appendix B. Additional regression results

Table B1: Cross-sectional regression (2014-15)

	Dependent variable: MFP growth					
	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.0485	0.0543	0.0554	0.0626	0.0711	0.0598
	(0.0435)	(0.0431)	(0.0432)	(0.0442)	(0.0452)	(0.0453)
Gap to frontier	0.102***	0.102***	0.103***	0.0995***	0.102***	0.102***
(lagged)	(0.0126)	(0.0126)	(0.0126)	(0.0120)	(0.0121)	(0.0129)
Age	-0.000350***	-0.000357***	-0.000342***	-0.000315***	-0.000356***	-0.000358***
	(6.30e-05)	(6.22e-05)	(6.27e-05)	(5.79e-05)	(6.14e-05)	(6.53e-05)
Employees (log)	0.0202***	0.0203***	0.0205***	0.0195***	0.0208***	0.0211***
	(0.00287)	(0.00287)	(0.00287)	(0.00272)	(0.00274)	(0.00290)
Digital	0.175***	0.119***	0.195***	0.158***	0.0668	0.0167***
Technologies	(0.0454)	(0.0364)	(0.0327)	(0.0455)	(0.0494)	(0.00347)
Observations	470,813	474,425	476,635	476,480	467,091	443,077
R-squared	0.059	0.059	0.060	0.057	0.058	0.059

Note: This table reports the estimates of the baseline equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, the firm's gap to this frontier, age and size (measured by the number of employees), and the average country-sector level adoption rates of individual digital technologies. The last column shows results for the 1st principal component of the five technologies. Firms at the sector-year frontier are excluded from the regressions. All regressions include sector and country-year fixed effects and are clustered at the country-sector level. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2014-15 for firms with more than 10 employees. Unweighted averages of each digital technology variable are used over the period 2014-15. ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database.

Table B2: Robustness to endogeneity concerns

Dependent variable: MFP growth. Digital technology: ERP software				
	Lagged adoption rate	Initial (2010) adoption rate	Lagged adoption rate (by prod. quartile)	Initial adoption rate (by prod. quartile)
Frontier growth	0.118**	0.124***	0.109**	0.110***
	(0.0500)	(0.0352)	(0.0495)	(0.0351)
Gap to frontier (lagged)	0.0931***	0.0990***	0.0723***	0.0725***
	(0.00508)	(0.0116)	(0.00871)	(0.0191)
Age	-0.000341***	-0.000335***	-0.000324***	-0.000324***
	(3.29e-05)	(5.88e-05)	(3.04e-05)	(5.13e-05)
Employees (log)	0.0170***	0.0199***	0.0180***	0.0179***
	(0.00119)	(0.00261)	(0.000908)	(0.00171)
ERP	0.0410**	0.0479**		
	(0.0197)	(0.0228)		
Quartile 2 (dummy)			-0.0608***	-0.0585***
			(0.00630)	(0.0126)
Quartile 3 (dummy)			-0.0659***	-0.0627***
			(0.00930)	(0.0192)
Quartile 4 (dummy)			-0.0799***	-0.0744***
			(0.0133)	(0.0281)
ERP (Quartile 1)			-0.0424*	-0.0330
			(0.0248)	(0.0305)
ERP (Quartile 2)			0.0438**	0.0574**
			(0.0214)	(0.0232)
ERP (Quartile 3)			0.0529***	0.0644**
			(0.0205)	(0.0251)
ERP (Quartile 4)			0.0698***	0.0746***
			(0.0200)	(0.0265)
Observations	1,182,855	1,226,046	1,182,855	1,184,608
R-squared	0.055	0.058	0.058	0.057

Note: This table reports estimates of the baseline equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, the firm's gap to this frontier, age and size (measured by the number of employees) and a digital adoption variable. The adoption variable in this table always relates to ERP software (time variation not being available for the other variables in the sample). Results are presented for the the adoption rate lagged by one year (column 1) and the initial adoption rate in the sample (year 2010, column 2). In the last two columns, the digital adoption variable is interacted with a dummy for each productivity quartile, as in Table 6. All regressions include sector and country-year fixed effects and are clustered at the country-sector level (except columns 1 and 3, which are clustered at the country-industry-year level since the digital variable varies at this level in these cases). Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2010-15 for firms with more than 10 employees. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database.

Table B3: Replacing routine intensity with knowledge intensity

	Dependent variable: MFP growth					
	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.222***	0.212***	0.218***	0.213***	0.230***	0.235***
	(0.0382)	(0.0374)	(0.0379)	(0.0373)	(0.0381)	(0.0392)
Gap to frontier (lagged)	0.104***	0.104***	0.105***	0.104***	0.107***	0.108***
	(0.0118)	(0.0114)	(0.0117)	(0.0115)	(0.0118)	(0.0127)
Age	-0.000304***	-0.000306***	-0.000295***	-0.000303***	-0.000372***	-0.000373***
	(5.89e-05)	(5.49e-05)	(5.86e-05)	(5.63e-05)	(5.75e-05)	(6.24e-05)
Employees (log)	0.0216***	0.0216***	0.0221***	0.0218***	0.0233***	0.0235***
	(0.00275)	(0.00267)	(0.00274)	(0.00269)	(0.00277)	(0.00297)
Digital technology	0.114*	0.121*	0.282***	0.202***	0.113	0.0309***
	(0.0642)	(0.0719)	(0.0625)	(0.0708)	(0.134)	(0.00633)
Digital technology	0.0476	-0.0554	-0.234*	-0.232**	-0.121	-0.0263***
# knowledge intensity	(0.0920)	(0.144)	(0.129)	(0.109)	(0.199)	(0.00892)
Observations	1,453,519	1,503,462	1,485,781	1,505,867	1,435,145	1,348,670
R-squared	0.062	0.062	0.063	0.062	0.064	0.064

Note: This table reports estimates of the baseline equation augmented with an interaction between digital technologies and knowledge intensity, defined as the share of labour compensation of personnel with tertiary education (see Annex A). All regressions include sector and country-year fixed effects and are clustered at the country-sector level. The last column shows results for the 1st principal component of the five technologies. Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2010-15 for firms with more than 10 employees. To maximise coverage, unweighted averages of each digital technology variable are used over the period 2010-15 and routine intensity refers to the average over the period 2010-15. ***, ** and * represent $p<0.01$, $p<0.05$ and $p<0.1$ respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database.

Table B4: Assessing the effects of skill shortages and routine intensity simultaneously

	Dependent variable: MFP growth					
	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.162***	0.133***	0.147***	0.142***	0.138***	0.150***
	(0.0377)	(0.0385)	(0.0380)	(0.0382)	(0.0381)	(0.0382)
Gap to frontier (lagged)	0.107***	0.105***	0.107***	0.106***	0.106***	0.107***
	(0.0137)	(0.0131)	(0.0134)	(0.0131)	(0.0130)	(0.0141)
Age	-0.000391***	-0.000394***	-0.000395***	-0.000394***	-0.000404***	-0.000404***
	(6.31e-05)	(6.21e-05)	(6.33e-05)	(6.17e-05)	(6.26e-05)	(6.79e-05)
Employees (log)	0.0230***	0.0227***	0.0234***	0.0228***	0.0229***	0.0233***
	(0.00312)	(0.00298)	(0.00308)	(0.00299)	(0.00297)	(0.00321)
Occupational shortage	-0.0372***	-0.0234	-0.0247**	-0.0223	-0.0215	-0.0269**
	(0.0130)	(0.0148)	(0.0117)	(0.0142)	(0.0145)	(0.0126)
Digital technology	0.147***	0.0310	0.207***	0.118**	0.0487	0.0216***
	(0.0491)	(0.0501)	(0.0429)	(0.0507)	(0.0848)	(0.00478)
Occupational shortage X digital technology	-0.306***	-0.110	-0.228**	0.00283	-0.158	-0.0129**
	(0.0861)	(0.111)	(0.0940)	(0.0663)	(0.0995)	(0.00537)
Routine intensity x digital technology	-0.130*	0.334***	0.369***	0.198**	0.0397	0.0199**
	(0.0706)	(0.102)	(0.114)	(0.0855)	(0.154)	(0.00780)
Observations	1,090,287	1,125,495	1,112,295	1,133,648	1,134,856	1,065,403
R-squared	0.063	0.062	0.063	0.063	0.062	0.063

Note: This table reports the estimates of the baseline equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, the firm's gap to this frontier, age and size (measured by the number of employees), average country-sector level adoption rates of individual digital technologies, an index capturing sector-level general occupational shortages, their interaction with the digital adoption variable, and an interaction between digital technology and routine intensity. All regressions include sector and country-year fixed effects and are clustered at the country-sector level. The last column shows results for the 1st principal component of the five technologies. Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2011-15 for firms with more than 10 employees. To maximise coverage, unweighted averages of each digital technology variable are used over the period 2010-15. ***, ** and * represent $p<0.01$, $p<0.05$ and $p<0.1$ respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database

Table B5: Baseline estimates controlling for additional variables

Panel A: controlling for intangible capital

	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.220***	0.211***	0.218***	0.214***	0.231***	0.238***
	(0.0384)	(0.0373)	(0.0378)	(0.0377)	(0.0383)	(0.0394)
Gap to frontier (lagged)	0.103***	0.103***	0.104***	0.103***	0.107***	0.107***
	(0.0131)	(0.0127)	(0.0129)	(0.0127)	(0.0132)	(0.0140)
Age	-0.000292***	-0.000292***	-0.000279***	-0.000291***	-0.000358***	-0.000358***
	(6.21e-05)	(5.83e-05)	(6.11e-05)	(5.98e-05)	(6.12e-05)	(6.63e-05)
Employees (log)	0.0198***	0.0198***	0.0201***	0.0198***	0.0218***	0.0221***
	(0.00289)	(0.00279)	(0.00285)	(0.00281)	(0.00288)	(0.00307)
Digital technology	0.139***	0.111***	0.172***	0.0795*	0.0404	0.0161***
	(0.0342)	(0.0371)	(0.0349)	(0.0427)	(0.0542)	(0.00382)
Intangible capital stock (log)	0.00159***	0.00155***	0.00154***	0.00165***	0.00148***	0.00136***
	(0.000413)	(0.000402)	(0.000404)	(0.000404)	(0.000437)	(0.000457)
Observations	1,229,670	1,269,595	1,255,462	1,270,278	1,203,570	1,136,071
R-squared	0.062	0.062	0.062	0.062	0.064	0.064

Panel B: controlling for capital expenditures

	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.201***	0.195***	0.201***	0.198***	0.216***	0.219***
	(0.0433)	(0.0420)	(0.0424)	(0.0426)	(0.0430)	(0.0441)
Gap to frontier (lagged)	0.102***	0.102***	0.103***	0.102***	0.106***	0.106***
	(0.0138)	(0.0135)	(0.0138)	(0.0135)	(0.0139)	(0.0147)
Age	-0.000399***	-0.000392***	-0.000383***	-0.000395***	-0.000494***	-0.000495***
	(7.94e-05)	(7.55e-05)	(7.83e-05)	(7.71e-05)	(8.20e-05)	(8.79e-05)
Employees (log)	0.0183***	0.0181***	0.0186***	0.0181***	0.0198***	0.0200***
	(0.00269)	(0.00261)	(0.00267)	(0.00264)	(0.00270)	(0.00284)
Capital expenditures (log)	0.00207***	0.00220***	0.00214***	0.00226***	0.00240***	0.00225***
	(0.000651)	(0.000632)	(0.000638)	(0.000641)	(0.000679)	(0.000698)
Digital technology	0.137***	0.110***	0.182***	0.0638	0.0137	0.0149***
	(0.0392)	(0.0401)	(0.0359)	(0.0473)	(0.0651)	(0.00404)
Observations	512,728	528,586	523,247	528,936	497,239	470,143
R-squared	0.065	0.065	0.066	0.065	0.068	0.068

Panel C: controlling for omitted variables bias

	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.169***	0.152***	0.161***	0.161***	0.163***	0.171***
	(0.0436)	(0.0432)	(0.0430)	(0.0436)	(0.0437)	(0.0444)
Gap to frontier (lagged)	0.102***	0.102***	0.103***	0.102***	0.103***	0.103***
	(0.0166)	(0.0162)	(0.0166)	(0.0162)	(0.0162)	(0.0171)
Age	-0.000492***	-0.000473***	-0.000479***	-0.000482***	-0.000501***	-0.000502***
	(9.56e-05)	(9.35e-05)	(9.53e-05)	(9.27e-05)	(9.44e-05)	(0.000101)
Employees (log)	0.0213***	0.0210***	0.0216***	0.0211***	0.0217***	0.0216***
	(0.00329)	(0.00325)	(0.00335)	(0.00325)	(0.00322)	(0.00341)
Regulatory impact	0.0114	0.0132	0.0303	0.0471	0.0224	0.0397
	(0.0454)	(0.0485)	(0.0424)	(0.0530)	(0.0503)	(0.0484)
Occupational shortage	-0.0353***	-0.0311**	-0.0266**	-0.0344**	-0.0318**	-0.0333**
	(0.0132)	(0.0136)	(0.0127)	(0.0138)	(0.0143)	(0.0132)
Capex (log)	0.00164**	0.00175**	0.00167**	0.00178**	0.00176**	0.00170**
	(0.000767)	(0.000748)	(0.000756)	(0.000751)	(0.000754)	(0.000785)
Digital Technology	0.164***	0.0695	0.214***	0.0861*	-0.0458	0.0162***
	(0.0533)	(0.0508)	(0.0510)	(0.0487)	(0.0848)	(0.00494)
Observations	343,890	352,794	348,719	355,672	354,379	335,739
R-squared	0.067	0.067	0.068	0.067	0.067	0.067

Note: These tables report estimates of the baseline equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, the firm's gap to this frontier, age and size (measured by the number of employees), augmented with the firm-level stock of intangible capital (Panel A), firm-level capital expenditures (Panel B), or a set of control variable accounting for the potential omitted variables bias (i.e. impact of regulatory barriers to competition, firm-level capital expenditures, and occupational shortages). The indicator of regulatory impact quantifies the potential costs of anti-competitive regulations in non-manufacturing sectors on all industries the United States that use the output of these sectors as intermediate inputs (see Égert and Wanner, 2016). The 1^{st} principal component is based on the five technologies of column 1-5. Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2010-15 for firms with more than 10 employees. To maximise coverage, unweighted averages of each digital technology variable are used over the period 2010-15. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database and the OECD Indicators of Product Market Regulations.

Table B6: Digital technology productivity benefits are diminished by technical and managerial skill shortages

Panel A: Testing for the effect of different skill shortages on the returns from high speed broadband

Dependent variable: MFP growth	Resource Management Skills	Management of Personnel Resources	Computers and Electronics	Technical Skills
Frontier growth	0.159***	0.160***	0.155***	0.152***
	(0.0372)	(0.0373)	(0.0368)	(0.0369)
Gap to frontier (lagged)	0.105***	0.105***	0.105***	0.105***
	(0.0133)	(0.0133)	(0.0132)	(0.0132)
Age	-0.000392***	-0.000392***	-0.000393***	-0.000394***
	(6.31e-05)	(6.31e-05)	(6.32e-05)	(6.30e-05)
Employees (log)	0.0227***	0.0227***	0.0227***	0.0227***
	(0.00303)	(0.00303)	(0.00303)	(0.00301)
High-speed broadband	0.164***	0.164***	0.149***	0.151***
	(0.0435)	(0.0429)	(0.0446)	(0.0443)
Skill shortage	-0.273***	-0.227***	-0.197***	-0.339***
	(0.0724)	(0.0597)	(0.0539)	(0.124)
Skill shortage	-1.020**	-0.898**	-0.705**	-2.236***
# High-speed broadband	(0.435)	(0.371)	(0.318)	(0.645)
Observations	1,106,487	1,106,487	1,106,487	1,106,487
R-squared	0.062	0.062	0.062	0.062

Panel B: The role of knowledge about computers and electronics for productivity returns

Dependent variable: MFP growth	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.155***	0.134***	0.145***	0.142***	0.142***	0.152***
	(0.0368)	(0.0374)	(0.0369)	(0.0376)	(0.0374)	(0.0374)
Gap to frontier (lagged)	0.105***	0.104***	0.106***	0.105***	0.105***	0.106***
	(0.0132)	(0.0126)	(0.0130)	(0.0126)	(0.0126)	(0.0135)
Age	-0.0003***	-0.0003***	-0.0003***	-0.0003***	-0.0004***	-0.0004***
	(6.32e-05)	(6.16e-05)	(6.27e-05)	(6.12e-05)	(6.15e-05)	(6.69e-05)
Employees (log)	0.0227***	0.0224***	0.0230***	0.0226***	0.0229***	0.0231***
	(0.00303)	(0.00289)	(0.00298)	(0.00289)	(0.00290)	(0.00310)
Digital Technology	0.149***	0.0584	0.195***	0.103**	0.0252	0.0166***
	(0.0446)	(0.0438)	(0.0406)	(0.0436)	(0.0668)	(0.00419)
Computers and electronics skill shortage	-0.197***	-0.180***	-0.164***	-0.186***	-0.169***	-0.176***
	(0.0539)	(0.0581)	(0.0508)	(0.0656)	(0.0635)	(0.0611)
Computers and electronics skill shortage # Digital Technology	-0.705**	0.141	-0.689*	0.0250	-0.287	-0.0363**
	(0.318)	(0.360)	(0.352)	(0.202)	(0.244)	(0.0163)
Observations	1,106,487	1,142,249	1,128,495	1,149,976	1,151,662	1,080,849
R-squared	0.062	0.062	0.062	0.062	0.062	0.062

Note: These tables reports the estimates of the baseline equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, the firm's gap to this frontier, age and size (measured by the number of employees), average country-sector level adoption rates of individual digital technologies, an index capturing sector-level skill shortages, and their effect on the productivity returns from digitalisation. *Resource management skills* refer the ability to allocate resources efficiently; *management of personnel resources* identifies how well managers motivate, develop and direct people as they work, and identify the best people for each job; *computer and electronics* refers to the knowledge of circuit boards, processors, chips, electronic equipment, computer hardware and software, including application and programming; and *technical skills* are associated with worker's capacity to design, set-up, operate and correct malfunctions, involving application of machines or technological systems (see OECD (2018), for more information). Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2011-15 for firms with more than 10 employees. To maximise coverage, unweighted averages of each digital technology variable are used over the period 2010-15. ***, ** and * represent $p<0.01$, $p<0.05$ and $p<0.1$ respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database.

Table B7: Interacting lagged gap with digital technologies

	Dependent variable: MFP growth					
	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.222***	0.211***	0.215***	0.215***	0.229***	0.235***
	(0.0382)	(0.0375)	(0.0382)	(0.0372)	(0.0381)	(0.0394)
Gap to frontier	0.104***	0.103***	0.103***	0.106***	0.107***	0.108***
(lagged)	(0.0114)	(0.0111)	(0.0113)	(0.00992)	(0.0116)	(0.0120)
Age	-0.000301***	-0.000308***	-0.000289***	-0.000294***	-0.000366***	-0.000355***
	(6.42e-05)	(5.45e-05)	(5.59e-05)	(5.42e-05)	(5.57e-05)	(5.94e-05)
Employees (log)	0.0216***	0.0214***	0.0219***	0.0222***	0.0234***	0.0235***
	(0.00273)	(0.00262)	(0.00268)	(0.00246)	(0.00272)	(0.00288)
Digital technology	0.149***	0.0761*	0.157***	0.0757*	0.0155	0.0139***
	(0.0425)	(0.0416)	(0.0361)	(0.0434)	(0.0593)	(0.00394)
Digital technology	-0.0192	-0.0827**	-0.0933**	-0.0853	-0.0816	-0.00763**
# Lagged gap	(0.0494)	(0.0378)	(0.0393)	(0.0523)	(0.0652)	(0.00323)
Observations	1,453,519	1,503,462	1,485,781	1,505,867	1,435,145	1,348,670
R-squared	0.062	0.063	0.064	0.063	0.064	0.065

Note: This table shows the results of the baseline equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, the firm's gap to this frontier, age and size (measured by the number of employees), augmented by an interaction term between digital technologies and the lagged gap to the frontier. All regressions include sector and country-year fixed effects and are clustered at the country-sector level. The 1^{st} principal component refers to the five technologies of column 1-5. Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2010-15 for firms with more than 10 employees. To maximise coverage, unweighted averages of each digital technology variable are used over the period 2010-15. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database.

Table B8: By productivity quartile without gap

	Dependent variable: MFP growth					
	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.174***	0.164***	0.170***	0.168***	0.181***	0.186***
	(0.0367)	(0.0358)	(0.0363)	(0.0363)	(0.0372)	(0.0384)
Age	-0.000309***	-0.000326***	-0.000312***	-0.000323***	-0.000398***	-0.000388***
	(4.75e-05)	(4.72e-05)	(4.75e-05)	(4.73e-05)	(4.75e-05)	(5.02e-05)
Employees (log)	0.0178***	0.0176***	0.0180***	0.0177***	0.0188***	0.0192***
	(0.00141)	(0.00136)	(0.00138)	(0.00140)	(0.00147)	(0.00154)
Quartile 2	-0.110***	-0.115***	-0.108***	-0.0767***	-0.0827***	-0.0879***
(dummy)	(0.00934)	(0.00779)	(0.00887)	(0.00682)	(0.00650)	(0.00492)
Quartile 3	-0.143***	-0.144***	-0.142***	-0.109***	-0.116***	-0.123***
(dummy)	(0.0113)	(0.0106)	(0.0114)	(0.00819)	(0.00786)	(0.00610)
Quartile 4	-0.207***	-0.210***	-0.208***	-0.170***	-0.178***	-0.186***
(dummy)	(0.0139)	(0.0143)	(0.0153)	(0.0111)	(0.0105)	(0.00803)
Digital (Quartile 1)	0.0694**	-0.0275	0.0780*	0.146***	0.108	0.00981**
	(0.0300)	(0.0412)	(0.0410)	(0.0531)	(0.0681)	(0.00387)
Digital (Quartile 2)	0.155***	0.0699*	0.154***	0.102**	0.0709	0.0142***
	(0.0305)	(0.0366)	(0.0316)	(0.0427)	(0.0585)	(0.00354)
Digital (Quartile 3)	0.155***	0.0559	0.152***	0.0962**	0.0673	0.0136***
	(0.0323)	(0.0347)	(0.0282)	(0.0396)	(0.0538)	(0.00311)
Digital (Quartile 4)	0.161***	0.0701**	0.165***	0.0914**	0.0593	0.0140***
	(0.0358)	(0.0336)	(0.0297)	(0.0401)	(0.0507)	(0.00314)
Observations	1,419,356	1,468,278	1,450,888	1,470,164	1,398,222	1,313,619
R-squared	0.057	0.056	0.057	0.056	0.056	0.057

Note: This table shows the results of the equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, age and size (measured by the number of employees), a dummy for each productivity quartile (omitting the first quartile for reference), and the interaction between digital technology adoption rates and each productivity quartile. Compared with the baseline equation the gap to the frontier is omitted from this regression. Quartile 1 refers to the bottom of the distribution (i.e. low productive firms), quartile 4 to the top. All regressions include sector and country-year fixed effects and are clustered at the country-sector level. The coefficient estimates of quartile 1 and 4 are always statistically different. The 1^{st} principal component refers to the five technologies of column 1-5. Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2010-15 for firms with more than 10 employees. To maximise coverage, unweighted averages of each digital technology variable are used over the period 2010-15. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database.

Table B9: The effects of digital adoption on productivity by size group

	Dependent variable: MFP growth					
	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.222***	0.211***	0.218***	0.215***	0.229***	0.236***
	(0.0383)	(0.0373)	(0.0378)	(0.0376)	(0.0381)	(0.0393)
Gap to frontier	0.103***	0.103***	0.104***	0.103***	0.106***	0.107***
(lagged)	(0.0116)	(0.0112)	(0.0115)	(0.0112)	(0.0116)	(0.0124)
Age	-0.000283***	-0.000288***	-0.000269***	-0.000281***	-0.000348***	-0.000346***
	(5.89e-05)	(5.57e-05)	(5.82e-05)	(5.71e-05)	(5.79e-05)	(6.30e-05)
Size class 2	0.0157***	0.0133***	0.0159***	0.0206***	0.0212***	0.0186***
(dummy)	(0.00343)	(0.00424)	(0.00398)	(0.00349)	(0.00316)	(0.00275)
Size class 3	0.0490***	0.0318***	0.0451***	0.0516***	0.0558***	0.0486***
(dummy)	(0.00727)	(0.00776)	(0.00800)	(0.00696)	(0.00656)	(0.00576)
Size class 4	0.0756***	0.0517***	0.0735***	0.0844***	0.0836***	0.0716***
(dummy)	(0.00920)	(0.00831)	(0.00925)	(0.00927)	(0.00816)	(0.00724)
Digital	0.142***	0.0753*	0.184***	0.110**	0.0906	0.0172***
(Size class 1)	(0.0343)	(0.0425)	(0.0365)	(0.0463)	(0.0600)	(0.00409)
Digital	0.149***	0.0909**	0.191***	0.0974**	0.0658	0.0169***
(Size class 2)	(0.0347)	(0.0411)	(0.0347)	(0.0444)	(0.0559)	(0.00392)
Digital	0.128***	0.121***	0.188***	0.0842*	0.0191	0.0156***
(Size class 3)	(0.0359)	(0.0370)	(0.0351)	(0.0447)	(0.0572)	(0.00387)
Digital	0.113***	0.128***	0.167***	0.0349	-0.0278	0.0126***
(Size class 4)	(0.0385)	(0.0375)	(0.0360)	(0.0439)	(0.0565)	(0.00382)
Observations	1,453,519	1,503,462	1,485,781	1,505,867	1,435,145	1,348,670
R-squared	0.062	0.062	0.063	0.062	0.064	0.064

Note: This table shows the results of the equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, age and size (measured by the number of employees), a dummy for each size group (omitting the first group for reference), and the interaction between digital technology adoption rates and each size group. All regressions include sector and country-year fixed effects and are clustered at the country-sector level. Compared with the baseline equation the gap to the frontier is omitted from this regression. Size group 1 captures firms with 10-20 employees, size group 2 firms from 21-50 employees, size group 3 firms with 51-250 employees, and size group 4 capture very large firms with more than 250 employees. In all cases, the coefficient estimates of size group 1 and 4 are statistically different. The 1^{st} principal component refers to the five technologies of column 1-5. Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2010-15 for firms with more than 10 employees. To maximise coverage, unweighted averages of each digital technology variable are used over the period 2010-15. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database.

Table B10: The effects of digital adoption on productivity by productivity quartile and size group

	Dependent variable: MFP growth					
	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.220***	0.205***	0.213***	0.210***	0.224***	0.231***
	(0.0391)	(0.0393)	(0.0400)	(0.0402)	(0.0404)	(0.0409)
Gap to frontier (lagged)	0.0985***	0.102***	0.102***	0.102***	0.107***	0.104***
	(0.0253)	(0.0251)	(0.0252)	(0.0248)	(0.0263)	(0.0270)
Age	-0.000503***	-0.000554***	-0.000518***	-0.000541***	-0.000684***	-0.000666***
	(9.24e-05)	(8.72e-05)	(8.91e-05)	(9.02e-05)	(9.46e-05)	(0.000101)
Employees (log)	0.00851***	0.00813***	0.00849***	0.00829***	0.0107***	0.0105***
	(0.00281)	(0.00266)	(0.00279)	(0.00280)	(0.00308)	(0.00312)
Dummy	-0.0650*	-0.0724*	-0.0817**	-0.0221	-0.0241	-0.0245
(High productive; Small)	(0.0352)	(0.0388)	(0.0389)	(0.0367)	(0.0367)	(0.0363)
Dummy	0.113***	0.0720***	0.109***	0.122***	0.119***	0.0852***
(Low productive; Large)	(0.0148)	(0.0174)	(0.0154)	(0.0122)	(0.0116)	(0.00720)
Dummy	-0.00980	-0.0287	-0.0156	0.0227	0.0213	0.0139
(High productive; Large)	(0.0337)	(0.0345)	(0.0366)	(0.0361)	(0.0364)	(0.0358)
Digital technology	0.126***	0.0236	0.0965**	0.0277	0.0165	0.00789
(Low productive; Small)	(0.0339)	(0.0514)	(0.0456)	(0.0758)	(0.0793)	(0.00490)
Digital technology	0.279***	0.205***	0.299***	0.0350	0.0898	0.0193***
(High productive; Small)	(0.0673)	(0.0573)	(0.0522)	(0.0624)	(0.0658)	(0.00468)
Digital technology	0.0352	0.0706	0.0110	-0.134	-0.316**	-0.00413
(Low productive; Large)	(0.0501)	(0.0811)	(0.0719)	(0.0985)	(0.137)	(0.00639)
Digital technology	0.216***	0.185***	0.210***	0.00977	-0.00122	0.0137***
(High productive; Large)	(0.0553)	(0.0455)	(0.0440)	(0.0565)	(0.0598)	(0.00448)
Observations	292,650	307,626	301,775	309,532	297,656	272,312
R-squared	0.083	0.084	0.084	0.082	0.084	0.085

Note: This table shows the results of the equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, age and size (measured by the number of employees), a dummy for each four different size/productivity groups (low productive and small; high productive and small; low productive and large; high productive and large),omitting the first group for reference, and the interaction between digital technology adoption rates and each group. All regressions include sector and country-year fixed effects and are clustered at the country-sector level. The 1^{st} principal component refers to the five technologies of column 1-5. Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2010-15 for firms with more than 10 employees. To maximise coverage, unweighted averages of each digital technology variable are used over the period 2010-15. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database.

Table B11: Skill shortages disproportionately curb the returns from digitalisation in low productive firms

	Dependent variable: MFP growth					
	High-speed broadband	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1st principal component
Frontier growth	0.136***	0.115***	0.125***	0.117***	0.119***	0.125***
	(0.0366)	(0.0372)	(0.0366)	(0.0370)	(0.0371)	(0.0385)
Gap to frontier (lagged)	0.0777***	0.0777***	0.0788***	0.0788***	0.0795***	0.0770***
	(0.0217)	(0.0206)	(0.0212)	(0.0209)	(0.0211)	(0.0216)
Age	-0.000355***	-0.000374***	-0.000366***	-0.000371***	-0.000387***	-0.000386***
	(5.09e-05)	(5.12e-05)	(5.09e-05)	(4.98e-05)	(5.08e-05)	(5.50e-05)
Employees (log)	0.0207***	0.0200***	0.0208***	0.0201***	0.0205***	0.0212***
	(0.00194)	(0.00186)	(0.00190)	(0.00183)	(0.00191)	(0.00203)
Digital (Quartile 1)	0.0969***	-0.0717	0.121**	0.168**	0.140	0.00602
	(0.0364)	(0.0519)	(0.0537)	(0.0695)	(0.108)	(0.00515)
Digital (Quartile 2)	0.208***	0.0470	0.201***	0.0839*	0.0336	0.0144***
	(0.0375)	(0.0448)	(0.0373)	(0.0464)	(0.0696)	(0.00407)
Digital (Quartile 3)	0.208***	0.0433	0.204***	0.0804*	0.0247	0.0157***
	(0.0425)	(0.0441)	(0.0377)	(0.0440)	(0.0660)	(0.00391)
Digital (Quartile 4)	0.239***	0.0648	0.234***	0.0961**	0.0519	0.0180***
	(0.0534)	(0.0431)	(0.0430)	(0.0471)	(0.0724)	(0.00432)
Digital (Quartile 1)	-0.269***	-0.153*	-0.213**	-0.307***	-0.581**	-0.00877
X Occupation shortage	(0.0730)	(0.0870)	(0.0912)	(0.116)	(0.244)	(0.0141)
Digital (Quartile 2)	-0.215***	-0.174***	-0.187***	-0.155***	-0.334***	-0.0210**
X Occupation shortage	(0.0401)	(0.0424)	(0.0356)	(0.0443)	(0.0890)	(0.00815)
Digital (Quartile 3)	-0.102**	-0.0461	-0.0451	-0.0327	-0.116	-0.0177***
X Occupation shortage	(0.0404)	(0.0494)	(0.0481)	(0.0587)	(0.105)	(0.00660)
Digital (Quartile 4)	0.0854	0.0933	0.122*	0.142*	0.239	-0.0160
X Occupation shortage	(0.0535)	(0.0674)	(0.0682)	(0.0794)	(0.146)	(0.0120)
Observations	1,067,412	1,102,176	1,088,798	1,109,472	1,110,981	1,042,252
R-squared	0.063	0.062	0.062	0.061	0.061	0.061

Note: This table shows the results of the equation where firm-level multifactor productivity growth is regressed on growth of the top 5 percent frontier firms in each sector-year cell, age and size (measured by the number of employees), an interaction between each productivity quartile and digital technologies, and the interaction between the latter and occupational shortages. Quartile 1 refers to the bottom of the distribution (i.e. low productive firms), quartile 4 to the top. All regressions include sector and country-year fixed effects and are clustered at the country-sector level. The 1^{st} principal component refers to the five technologies of column 1-5. Firms at the sector-year frontier are excluded from the regressions. Regressions are based on firm-level data from 20 countries and 22 sectors (NACE Rev 2, 10-82) over the period 2010-15 for firms with more than 10 employees. To maximise coverage, unweighted averages of each digital technology variable are used over the period 2010-15. ***, ** and * represent p<0.01, p<0.05 and p<0.1 respectively.
Source: OECD calculations based on ORBIS and Eurostat, Digital Economy and Society Statistics, comprehensive database.

Table C1: Literature review

Focus	Author and year	Title	Measure of ICT	Time	Country coverage	Main source of data	Main finding
US-studies	(Brynjolffson, 1996)	Paradox Lost? Firm-level Evidence on the Returns to Information Systems Spending	Computer Capital; Information System Staff	1987-1991;	United States	Firm level data; International Data Group (IDG) annual survey of IT spending; Compustat.	IT capital and labour are significantly related to output, and their marginal products are larger than their non-IT counterparts. (Black, 2001)
US-studies	(Brynjolfsson and Hitt, 2000)	Computing Productivity: Firm-Level Evidence,	Computer equipment	1987-1994;	United States	Firm-level data; Computer Intelligence InfoCorp (CII), Compustat.	IT capital makes a significant contribution to productivity and output growth in the short run (1 year lag), but the contribution is five times larger in the long run (5-7 years lag).
US-studies	(Black, 2001)	How to Compete. The impact of Workplace Practices and Information Technology on Productivity	Share of workers using computers	1987-1993	United States	Plant-level data; Bureau of the Census' Longitudinal Research Database (LRD)	The greater the proportion of non-managerial workers using computers, the higher plant productivity.
US-studies	(Hunton, Lippincott and Reck, 2003)	Enterprise resource planning systems: comparing firm performance of adopters and non-adopters	Enterprise Resource Planning (ERP)	1990-1998	United States	Firm-level data; Compustat; Hayes DC,	Return on assets (ROA), return on investment (ROI), and asset turnover (ATO) were significantly better over a 3-year period for adopters, as compared to nonadopters.
US-studies	(Nicolau, 2005)	Organizational performance effects of ERP systems usage: The impact of post-implementation changes	Enterprise Resource Planning (ERP)	2004	United States	Firm-level data; Lexis/Nexis database	Subsequent changes in ERP systems often help resolve or surface implementation issues that affect subsequent use of and success from the use of such systems. Specific findings indicate that ERP-adopting firms, which initiate early enhancements in the form of either add-ons or upgrades, may enjoy superior differential financialperformance in comparison to other ERP-adopting firms' differential performance.
US-studies	(Aral, Brynjolfsson and Wu, 2006)	"Which Came First, IT or Productivity? Virtuous Cycle of Investment and Use in Enterprise Systems"	Enterprise Resource Planning (ERP), Customer Relationship Management Systens (CRM), Supply Chain Management Systems (SCM).	1998-2005;	United States	Firm-level data; HCM vendor data; Compustat	Firms that successfully implement IT, react by investing in more IT. Our work suggests replacing either-or views of causality with a positive feedback loop conceptualization in which successful IT investments initiate a virtuous cycle of investment and gain
US-studies	(Bartel, Ichniowski and Shaw, 2007)	How Does Information Technology Affect Productivity? Plant-Level Comparisons of-Product Innovation, Process Improvement, and Worker Skills	IT equipment various measures, e.g. number of computer numerically controlled machines)	1999-2003	United States	Specific survey on valve-making plants	New IT investments improve the efficiency of all stages of the production process by reducing setup times, run times, and inspection times. Adoption of new IT-enhanced capital equipment coincides with increases in the skill requirements of machine operators, notably technical and problem-solving skills, and with the adoption of new human resource practices to support these skills.
US-studies	(Aral, Brynjolfsson and Wu, 2012)	Three-Way Complementarities:Human Resource Analytics, Performance Pay, and InformationTechnology	Enterprise Resource Planning (ERP), Customer Relationship Management Systens (CRM), Supply Chain Management Systems (SCM).	1995-2002;	United States	Firm-level data; HCM vendor data; Compustat	Human Capital Management software adoption is associated with a disproportionately large productivity premium when it is implemented as asystem of organizational incentives, but has little or no benefit when adopted in isolation
US-studies	(Acemoglu et al., 2014)	Return of the Solow Paradox? IT, Productivity, and Employment in U.S. Manufacturing	IT intensity as (1) the ratio of sector computer (IT) expenditures to total capital expenditures; and (2) usage of a set of manufacturing technologies	1977, 1982, 1987, 1992, 2002, and 2007;	United States	Plant-level data; US Census Bureau's 1988 and 1993 Survey of Manufacturing Technology (SMT)	IT has no effect on output per worker on the manufacturing sector outside the computer-producing sector.

Table C1: Literature review (continued)

Focus	Author and year	Title	Measure of ICT	Time	Country coverage	Main source of data	Main finding
US-studies	(Bloom, 2017)	What Drives Differences in Management?	IT investment (in computers) per employee	2005-2010	United States	Plant-level data; US Census Bureau's Management and Organizational Practices Survey; Business R&D and Innovation Survey	US manufacturing sector, dispersion in IT expenditures per employee explains around 8% of the productivity dispersion, while management quality explains around 17% of the spread in TFP.
US-studies	(Brynjolfsson et al., 2008)	Scale Without Mass: Business Process Replication and Sector Dynamics	IT capital comprising computer hardware software	1987-2006	United States	Sector-level (IT) and firm-level data (TFP); Bureau of Economic Analysis's (BEA) "Tangible Wealth Survey"; Compustat	Using case studies, the authors illustrate how IT has enabled firms to more rapidly replicate improved business processes throughout an organization, thereby increasing productivity, market share and market value.
US-studies	(Dinlersoz, 2018)	Automation, Labor Share, and Productivity:Plant-Level Evidence from U.S. Manufacturing	Current and future dependenceof operations on technology, as well as about past and future investment in technology.	1991	United States	Plant-level data; U.S. Census Bureau's Survey on Manufacturing Technology 1991.	More automated establishments have lower production labor share and higher capital share, and a smaller fraction of workers in production who receive higher wages. These establishments also have higher labor productivity and experience larger long-term labor share declines.
Cross-country studies	(Basu, 2003)	The Case of Missing Productivity Growth	IT capital stock (computer, software, communication equipment)	1995-2000	United States; United Kingdom	Sector-level : Bureau of Labour Statistics; Bank of England	Difference in total factor productivity (TFP) between the United States and the United Kingdom from 1995 onwards can be explained by a combination of unmeasured investments in (intangible) organisational capital and ICTs, and in particular the innovation these investments induce.
Cross-country studies	(Gust and Marquez, 2004)	International comparisons of productivity growth: the role of information technology and regulatory practices$	ratio of IT expenditures to GDP	1992 to 1999	13 industrial countries	Country-level; OECD STAN	Burdensome regulatory environments and, in particular, regulations affecting labour market practices have impeded the adoption of information technologies and have slowed productivity growth in a number of industrial countries.
Cross-country studies	(Van Ark and Inklaar, 2006)	Catching up or getting stuck? Europe's troubles to exploit ICT's productivity potential	Catching up or getting stuck? Europe's troubles to exploit ICT's productivity potential	2001-2004	France, Germany, Netherlands, United Kingdom, United States	Sector-level; pre-EU KLEMS dataset i.e.the 60 Sector Database of the Groningen Growth and Development Centre (GGDC)	The relationship between ICT investments and productivity is U-shaped, whereby the initial adoption phase is followed by a period of experimentation during which ICT and productivity are negatively related. However, complementary investments eventually lead to gains from ICT in line with its marginal costs.
Cross-country studies	(Van Ark, 2008)	The Productivity Gap between Europe and the United States: Trends and Causes	ICT capital	1995-2004	EU, United States	Country-level data: EU KLEMS database	The European productivity slowdown is attributable to the slower emergence of the knowledge economy in Europe compared with the United States, partly due to lower growth contribution from ICT investments.
Cross-country studies	(Bloom, Sadun and Van Reenen, 2012)	American do IT better: US Multinationals and the Productivity Miracle"	PC and laptop per worker	1999-2006	EU (France, Germany, Italy, Poland, Portugal, Sweden and the UK)	Firm-level data: UK Census Bureau; CEP Management Survey; Harte-HanksIT panel	US firms' IT-related productivity advantages are primarlily due to their "tougher" management practices.
Cross-country studies	(Bartelsman, 2013)	ICT, Reallocation and Productivity	N.A.	N.A.,	EU countries	N.A.	Owing to the on-going advances in ICT, much higher growth is technologically feasible, but a considerable amount of churn and reallocation across firms in the market sector is needed.

Table C1: Literature review (continued)

Focus	Author and year	Title	Measure of ICT	Time	Country coverage	Main source of data	Main finding
Cross-country studies	(Hagsten et al., 2013)	The Multifaceted Nature of ICT: Final report of the ESS-Net on linking of microdata to analyse ICT impact.	Broadband-enabled employees.	2004-2009	EU countries	ESSLait Micro Moments Database	Services (resp. manufacturing) firms in ten (resp. eight) out of 14 countries exhibit a significant relationship between broadband employees and labour productivity.
Cross-country studies	(Evangelista, Guerrieri and Meliciani, 2014)	The economic impact of digital technologies in Europe	Composite ICT indicators	2004-2008	EU countries	European Digitalization Development Index	Digitalisation may drive productivity and employment growth. Inclusive policies may contribute to bridge the gap between the most favoured and the disadvantaged parts of the population
Cross-country studies	(Acharya, 2016)	ICT use and total factor productivity growth: intangible capital or productive externalities	ICT capital	1973-2004	EU and US	Sector-level data: EU KLEMS	Unmeasured intangible capital accumulation rather than productive externalities were at the core of the US (and to some extent EU) TFP growth in the mid '90s.
Cross-country studies	(Corrado, Haskel and Jona-Lasinio, 2017)	Knowledge Spillovers, ICT and Productivity Growth	ICT capital	1998-2007	EU countries	EUKLEMS	The marginal impact of ICT capital is higher when it is complemented with intangible knowledge based capital. More specifically, their study shows that ICT intensive industries have better productivity outcomes in countries that are more KBC intensive, in particular with relative higher investments in organisational capital
Cross-country studies	(Cette, Lopez and Mairesse, 2017)	Upstream Product Market Regulations, ICT, R&D and Productivity	ICT capital	1987-2007	EU and US	OECD STAN; EU-KLEMS	ICT capital increases are an important channel to increase sector level MFP when upstream sectors are deregulated.
Cross-country studies	(Bartelsman, Van Leeuwen and Polder, 2017)	CDM using a cross-country micro moments database	Enterprise Resource Planning (ERP), Customer Relationship Management Systens (CRM), Supply Chain Management Systems (SCM).	2006-2009;	EU countries	ESSLait Micro Moments Database	Innovative activity contributes to aggregate productivity even while the average effect at the firm level is insignificant. Moreover, the combined use of digital technologies leads to within-firm productivity increases.
Non-US studies	(Bugamelli and Pagano, 2004)	Barriers to investment in ICT	ICT capital stock	1995-1997	Italy	Firm-level data: 'Centraledei Bilanci' (Company Accounts Data Service, CADS); 'Indagine sulle Imprese Manifatturiere' (Survey ofManufacturing Firms, SMF) by Mediocredito Centrale	The ICT marginal product exceeds its user cost, possibly due to the lack of complementary investment in human capital and the lack of a reorganization of the workplace.
Non-US studies	(Wieder et al., 2006)	The impact of ERP systems on firm and business process performance	ERP and SCM	2001	Australia	Firm level data; Survey conducted by the Australian BusinessJournal "BRW"	Except when both technologies were combined, no significant performance differences were found between ERPS adopters and non-adopters, either at the business process level, or at the overall firm level. While it could be confirmed that the longer the experience of firms with ERP, the higher their overall performance, no evidence was found of a similar effect on business process (supply chain) performance.
Non-US studies	(Castiglione, 2012)	Technical efficiency and ICT investment in Italian manufacturing firms	ICT investments	1995-2003	Italy	Firm-level survey data from Mediocredito Centrale Capitalia	ICT investments positively and significantly affect firms' technical efficiency.

Table C1: Literature review (continued)

Focus	Author and year	Title	Measure of ICT	Time	Country coverage	Main source of data	Main finding
Non-US studies	(Engelstätter, 2009)	Enterprise systems and labor productivity: disentangling combination effects	Share of computer workers, ERP, SCM, and CRM systems	2004; 2006	Germany	Firm-level data; phone interview conducted by Centre for European Economic Research (ZEW).	Replicating Aral, Brynjolfsson and WU (2006) using similar data the authors find a positive correlation between labor productivity and various measures of IT. The authors also show evidence of the complementarity between different measures.
Non-US studies	(Hall, Lotti and Mairesse, 2012)	Evidence on the impact of R&D and ICT investment on innovation and productivity in Italian firms	ICT investment expenditure	1995-2006,	Italy	Firm-level data: Unicredit "Survey on Manufacturing Firms"	R&D and ICT are both strongly associated with innovation and productivity, with R&D being more important for innovation, and ICT investment being more important for productivity
Non-US studies	(Akerman, Gaarder and Mogstad, 2013)	The skill complementarity of broadband internet	Broadband subscription	2001-2007	Norway	Firm-level data; Annual Community Survey on ICT Usage of Firms by Statistics Norway	Broadband internet complements skilled workers in executing non-routine abstract tasks, and substitutes for unskilled workers in performing routine tasks.
Non-US studies	(Pellegrino, 2017)	Diagnosing the Italian Disease	IT capital	1984-2006	Italy	Sector-level: EU KLEMS	Italy's slowdown was likely caused by the failure of its firms to take full advantage of the ICT revolution. While many institutional features can account for this failure, a prominent one is the lack of meritocracy in the selection and rewarding of managers. Familyism and cronyism are the ultimate causes of the Italian disease.
Non-US studies	(Dhyne et al., 2018)	IT and Productivity: A firm level analysis	IT purchases by firms	2002-2013	Belgium	Firm-level data; VAT transaction data obtained from tax authorities.	Using VAT transaction data between Belgium firms, this paper looks at the various dimensions of sector and firm level heterogeneity in returns of IT capital. IT investments are found to be more productivity-enhancing in the manufacturing sector and in large firms.
Non-US studies	(Chevalier and Luciani, 2018)	Computerization, labor productivity and employment: impacts across industries vary with technological level	Office and computing machinery investment	1994-2007	France	Sector and firm-level data (BRN and DADS), manufacturing sector	For the whole IT-using manufacturing sector, computerization is associated with positive but fragile effects on labor productivity, and to unambiguous declines in employment.
Non-US studies	(DeStefano, Kneller and Timmis, 2018)	Broadband infrastructure, ICT use and firm performance: Evidence for UK firms	ADSL broadband	1999-2005	United Kingdom	Ci Technology Database (CiTDB)	ICT causally affects firm size (captured by either sales or employment) but not productivity.
Non-US studies	(Mohnen, Polder and Van Leeuwen, 2018)	R&D and Organizational Innovation: Exploring Complementarities in Investment and Production	ICT investment (hardware only)	2008-2014	Netherlands	Firm-level data, Dutch Investment Survey	Investments in ICT, R&D and organisational capital are complementary, in the sense that investing in one increases the probability of investing in another one because joint investments lead to higher TFP growth than individual investments.
Other	(Brynjolfsson and Hitt, 2000)	Beyond Computation: Information Technology, Organizational Transformation and Business Performance	N.A.	N.A.	N.A.	N.A.	Relying primarily on case studies, but also on preliminary research the authors document that computerization without changes in work practices usually fails at delivering an increase in efficiency. For example, technology aiming at facilitating the interactions between a firm and its suppliers will be efficient only if the entire supply chain is reorganised accordingly.
Other	(Dedrick, Gurbaxani and Kraemer, 2003)	Information Technology and Economic Performance: A Critical Review of the Empirical Evidence	N.A.	1987-2002	N.A.	N.A.	In a conclusive review of over 50 scholarly studies on ICT and productivity published between 1987 and 2002, the authors find that "the productivity paradox as first formulated has been effectively refuted.
Other	(Syverson, 2011)	What Determines Productivity?	N.A.	N.A.	N.A.	N.A.	Provides a literature review of IT-related productivity gains.