OECD Economics Department Working Papers No. 1476

Digital technology diffusion:
A matter of capabilities,
incentives or both?

**Dan Andrews,
Giuseppe Nicoletti,
Christina Timiliotis**

<https://dx.doi.org/10.1787/7c542c16-en>

Cancels & replaces the same document of 24 July 2018

**DIGITAL TECHNOLOGY DIFFUSION: A MATTER OF CAPABILITIES,
INCENTIVES OR BOTH?**

ECONOMICS DEPARTMENT WORKING PAPERS No. 1476

By Dan Andrews, Giuseppe Nicoletti and Christina Timiliotis

OECD Working Papers should not be reported as representing the official views of the OECD or of its member countries. The opinions expressed and arguments employed are those of the author(s).

Authorised for publication by Luiz de Mello, Director, Policy Studies Branch, Economics Department.

All Economics Department Working Papers are available at www.oecd.org/eco/workingpapers.

JT03439096

OECD Working Papers should not be reported as representing the official views of the OECD or of its member countries. The opinions expressed and arguments employed are those of the author(s).

Working Papers describe preliminary results or research in progress by the author(s) and are published to stimulate discussion on a broad range of issues on which the OECD works.

Comments on Working Papers are welcomed, and may be sent to OECD Economics Department, 2 rue André Pascal, 75775 Paris Cedex 16, France, or by e-mail to eco.contact@oecd.org.

All Economics Department Working Papers are available at www.oecd.org/eco/workingpapers

This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

On 3 May 2018, the OECD Council invited Lithuania to become a Member. At the time of preparation, the deposit of Lithuania's instrument of accession to the OECD Convention was pending and therefore Lithuania does not appear in the list of OECD Members and is not included in the OECD zone aggregates.

On 25 May 2018, the OECD Council invited Colombia to become a Member. At the time of preparation, the deposit of Colombia's instrument of accession to the OECD Convention was pending and therefore Colombia does not appear in the list of OECD Members and is not included in the OECD zone aggregates.

© OECD (2018)

You can copy, download or print OECD content for your own use, and you can include excerpts from OECD publications, databases and multimedia products in your own documents, presentations, blogs, websites and teaching materials, provided that suitable acknowledgment of OECD as source and copyright owner is given. All requests for commercial use and translation rights should be submitted to rights@oecd.org

ABSTRACT/RÉSUMÉ

Digital technology diffusion: a matter of capabilities, incentives or both?

Insufficient diffusion of new technologies has been quoted as one possible reason for weak productivity performance over the past two decades (Andrews et al., 2016). This paper uses a novel data set of digital technology usage covering 25 industries in 25 European countries over the 2010-16 period to explore the drivers of digital adoption across two broad sets of digital technologies by firms, cloud computing and back or front office integration. The focus is on structural and policy factors affecting firms' capabilities and incentives to adopt -- including the availability of enabling infrastructures (such as high-speed broadband internet), managerial quality and workers skills, and product, labour and financial market settings. We identify the effects of structural and policy factors based on the difference-in-difference approach pioneered by Rajan and Zingales (1998) and show that a number of these factors are statistically and economically significant for technology adoption. Specifically, we find strong support for the hypothesis that low managerial quality, lack of ICT skills and poor matching of workers to jobs curb digital technology adoption and hence the rate of diffusion. Similarly our evidence suggests that policies affecting market incentives are important for adoption, especially those relevant for market access, competition and efficient reallocation of labour and capital. Finally, we show that there are important complementarities between the two sets of factors, with market incentives reinforcing the positive effects of enhancements in firm capabilities on adoption of digital technologies.

JEL Classification codes: D24, J24, O32, O33.

Keywords: Digital technologies, productivity, diffusion, digital skills.

Diffusion des technologies numériques : une question de capacités, d'incitations ou des deux?

La diffusion insuffisante des nouvelles technologies est citée comme l'une des causes possibles de la faiblesse des gains de productivité observée depuis deux décennies (Andrews et al., 2016). S'appuyant sur un ensemble de données inédit sur l'utilisation des technologies numériques dans 25 secteurs et 25 pays européens au cours de la période 2010-16, cette étude examine les moteurs de l'adoption de deux groupes de technologies numériques par les entreprises, l'informatique en nuage et de front et back office. Elle s'intéresse en particulier aux facteurs structurels et politiques ayant une influence sur la capacité et les incitations des entreprises à franchir le cap – mise à disposition des infrastructures nécessaires (notamment de l'internet haut débit), disponibilité des qualités managériales et des compétences idoines des travailleurs, ou encore physionomie des marchés de produits, du travail et de la finance. On y met en lumière les effets de ces facteurs structurels et politiques en se fondant sur la méthode des doubles différences expérimentée pour la première fois par Rajan et Zingales (1998), avant de montrer qu'un certain nombre d'entre eux sont statistiquement et économiquement déterminants dans l'adoption des technologies. De fait, l'étude accrédite l'hypothèse selon laquelle de faibles qualités managériales, un manque de compétences en TIC et une inadéquation entre l'offre et la demande d'emploi freinent l'adoption des technologies numériques et donc leurs taux de diffusion à travers les entreprises. De même, les faits montrent que les mesures de stimulation des marchés jouent un rôle déterminant dans leur adoption, notamment celles qui ont trait à l'accès aux marchés, à la concurrence et à la réaffectation efficiente de la main-d'œuvre et du capital. Enfin, l'étude met en évidence d'importantes complémentarités entre les deux ensembles de facteurs, les mesures de stimulation des marchés contribuant à renforcer les effets positifs de l'amélioration des capacités des entreprises sur l'adoption des technologies numériques.

Classification JEL : D24, J24, O32, O33.

Mots-clés: technologies numériques, productivité, diffusion, compétences numériques.

Table of contents

Digital technology diffusion: a matter of capabilities, incentives or both?	6
1. Introduction.....	6
1.1. Capabilities, incentives and adoption of digital technologies.....	9
1.1.1. Breakdown of the diffusion machine	9
1.1.2. The adoption of digital technologies still lags behind its potential	10
1.2. The data on digital technologies, capabilities and incentives	15
1.2.1. Indicators of digital technology adoption.....	15
1.2.2. Capabilities and incentives	17
1.3. The influence of capabilities and incentives on digital adoption.....	20
1.3.1. Some suggestive evidence.....	20
1.3.2. Empirical approach	21
1.3.3. Results	25
1.4. Complementarity between capabilities and incentives	38
1.5. Policy discussion and further research.....	41
1.5.1. Policy implications	41
1.5.2. Research agenda	43
References	45
Annex A. Description of the data and variables used	51
Annex B. Robustness and additional results	65
Annex C. Policy initiatives bridging the digital gap	75
Policies encouraging the diffusion of high-speed broadband: some examples	75
Policies initiatives promoting digital skills	76
The EU data protection framework	77
Annex D. Digital technologies covered by the analysis	78
Cloud Computing (CC)	78
Enterprise Resource Planning (ERP)	78
Customer Relationship Management systems (CRM)	79

Tables

Table 1. Summary statistics of policy and structural factors.....	17
Table 2. Proxies for capability and incentive factors	25
Table 3. Capabilities and digital adoption.....	28
Table 4. Market incentives and digital adoption	31
Table 5. The joint effects of incentives and capabilities	32
Table 6. The complementarity between incentives and capabilities: the effects of improving managerial practices on adoption depend on the market environment.....	40

Table A.1. Description of variables and sources	51
Table A.2. Country coverage.....	53
Table A.3. Summary statistics (average values).....	53
Table A.4. Summary statistics for digital technologies, by year	54
Table A.5. Average adoption rates by industry (2010-2016)	55
Table A.6. High-speed broadband connections are critical to the adoption of all digital	57
Table A.7. The enabling role of Cloud Computing for ERP and CRM adoption	57
Table A.8. Correlations across digital technologies	58
Table B.1. Principal Component Analysis	65
Table B.2. Baselines estimates controlling for GDP	66
Table B.3. Placebo tests.....	67
Table B.4. EPL interacted with job turnover.....	68
Table B.5. Capabilities and digital adoption – robustness to a different exposure variable.....	69
Table B.6. Testing the validity of knowledge intensity as exposure variable	70
Table B.7. Digital adoption and capabilities: instrumental variable approach.....	71
Table B.8. Digital adoption and capabilities: instrumental variable approach.....	72
Table B.9. Univariate regression results: robustness to dropping one sector at a time	73
Table B.10. Univariate regression results: robustness to dropping one country at a time.....	74
Table C.1. Bridging the digital gap	76
Table C.2. Policy initiatives in support of vocational training and higher education in ICT	76

Figures

Figure 1. The diffusion of digital technologies is uneven across countries and industries	12
Figure 2. Use of high-speed broadband (>30 Mbit/s) is associated with higher digital.....	20
Figure 3. Structural policies and the diffusion of complex cloud computing.....	21
Figure 4. The complementarity of training with adoption is stronger for the low-skilled	27
Figure 5. Economic significance (Capabilities)	35
Figure 6. Economic significance (Incentives)	36
Figure 7. A market environment favourable to incentives boosts the impact of enhanced managerial practices on the adoption rate of cloud computing.....	41
Figure A.1. Enterprises using cloud computing services, by firm size, 2016	56
Figure A.2. Use of enterprise resource planning software, by firm size, 2015	56
Figure A.3. The quality of management.....	59
Figure A.4. Individuals using the Internet to interact with public authorities (E- Government) by age, 2016	60
Figure A.5. Education and training	61
Figure A.6. Entry and exit.....	62
Figure A.7. Labour market settings.....	63
Figure A.8. Access to capital, average 2010-2015	63
Figure A.9. R&D fiscal incentives, 2013	64
Figure A.10. Digital trade openness	64
Figure B.1. The correlation between knowledge intensity and the share of high-routine employment.....	68

Digital technology diffusion: a matter of capabilities, incentives or both?

Dan Andrews, Giuseppe Nicoletti and Christina Timiliotis¹

1. Introduction

1. The rapid development of information and communication technologies over the past 15 years has coincided with a generalised slowdown in aggregate productivity growth, the so-called modern productivity paradox (Acemoglu et al., 2014; Brynjolfsson et al., 2017). Barriers to technology diffusion across firms, with laggard firms increasingly falling behind the best practice ones, have been identified as one potential explanation of this paradox (Andrews et al., 2015 and 2016). For instance, while many firms now have access to broadband networks, the diffusion of more advanced digital tools and applications is far from complete and differs significantly across countries (McKinsey Global Institute, 2018). Therefore, it is important to understand the drivers of technology adoption.

2. While research in this area has been extensive over the past two decades, it has either taken a broad approach considering the determinants of ICT investment as a whole (Guerrieri et al., 2010; Cetto et al., 2011) or has focused narrowly on the adoption of specific technologies mostly at the single country level (see, for instance, the survey in Oliveira and Martins, 2011). Yet, recent findings show that drivers of adoption differ across information and communication technologies (De Stefano et al., 2017), suggesting that a disaggregate approach covering a range of technologies is preferable. Moreover, cross-country variation is useful to identify the structural and policy factors that can potentially explain differences in technology adoption. For instance, the well-documented complementarity between technology use and workers' skills (Machin and van Reenen, 1998; Autor et al., 2003a; Bartel et al., 2007) can become an obstacle to diffusion where the necessary human capital is in short supply. Similarly, firms' incentives to adopt new technologies are related to competitive pressures (Aghion and Griffith, 2005, and references therein), which in turn are heavily influenced by policies that affect the business environment.

¹ Corresponding authors are: Dan Andrews (Australian Department of the Treasury; Dan.Andrews@treasury.gov.au), Giuseppe Nicoletti (OECD Economics Department; Giuseppe.Nicoletti@oecd.org) and Christina Timiliotis (OECD Economics Department; Christina.Timiliotis@oecd.org). The authors are grateful to Luiz de Mello, Peter Gal, Mustafa Utku Ozmen, Balasz Stadler (OECD Economics Department) and OECD delegates to Working Party 1 of the Economic Policy Committee for their valuable comments. We especially acknowledge comments by reviewers from the Directorate for Science, Technology and Innovation, which were extremely useful for improving a previous draft of this paper. We also thank Christoph Münzer (Wirtschaftsverband Industrieller Unternehmen Baden e.V.) and Jonathan von Rüden (SAP) for sharing their perspective on the questions addressed by this paper. Further thanks go to Sarah Michelson (OECD Economics Department) for excellent editorial support.

3. Against this background, this paper exploits cross-country industry-level data to explore the link between structural factors and diffusion of a range of digital technologies across firms in a cross-section of 24 European countries and Turkey and 25 manufacturing and services industries over 2010-2016. To our knowledge, this is the first empirical study to cover such a wide set of countries and technologies contributing to two streams of research, the link between human capital and adoption on the one hand and the link between the business environment and adoption on the other.

4. More specifically, we test whether cross-country differences in digital adoption rates at the industry level (measured as the share of firms adopting specific digital technologies) stem from differences in firms' capabilities and incentives to adopt new technologies. We relate capabilities to the complementary intangible investments required for successful adoption, such as organisational capital, skills and the efficient allocation of human talents, while we include among market incentives the strength of market entry and discipline that make it difficult for technologically backward firms to remain in the market; the ease with which firms can adjust their labour force to implement new production methods; and access to capital and labour for firms that wish to adopt the latest technologies. A further contribution is that we also explore the possible synergies between these two sets of factors and test whether the market environment affects the link between capabilities and adoption rates.

5. While the list of digital technologies used in firms grows by the day, the focus of this study is on two sets of core digital technologies, namely cloud computing (standard and complex) and back or front office integration – as facilitated by Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) software – for which cross-country industry-level data on firm-level adoption rates are available. We also consider high-speed broadband internet as an enabler of these technologies and systematically control for its availability. Insofar as these technologies are linked to productivity improvements,² and because their diffusion rates are far from complete, findings concerning the drivers of their adoption by firms are informative of the potential for productivity improvements via adoption and could apply to a broader set of technologies.

6. We start by demonstrating a statistically significant positive link between the penetration of high-speed broadband and the diffusion of each of these technologies. This finding validates the intuition that improving the roll-out of high quality broadband infrastructure is complementary to the adoption of more sophisticated digital applications, and constitutes the backbone of a digital economy.³

² There is growing empirical evidence on the effects of ICT and digital adoption on firm performance (Draca et al., 2007; Bloom et al., 2012a; Bloom et al., 2014). Recent papers include van Reenen et al. (2017), Bartelsman et al. (2017), Fabling and Grimes (2016) and Dhyne et al. (2017). A companion paper (Gal et al., forthcoming) explores in more detail the link between adoption of the same digital technologies covered here and firm-level productivity performance.

³ These results are consistent with the findings by Fabling and Grimes (2016) that diffusion of ultrafast broadband in New Zealand firms has been complementary to important organisational investments that require adoption of digital technologies.

7. We then explore the effects of capabilities and incentives on digital technology diffusion by exploiting the idea that structural factors are likely to be more binding for some industries than others – due to the inherent technological characteristics of the industry – an approach in the spirit of Rajan and Zingales (1998). In terms of capabilities, we focus on measures of management quality, the availability of ICT skills and training, the matching of skills to jobs, and the role of E-Government forging worker’s digital affinity in their day-to-day life. As for market incentives, we consider indicators of the ease of firm entry and exit, of barriers to competition and digital trade, of the adaptability of the workforce (measured by the ease of hiring and firing) and of access to private equity.

8. The results should be interpreted with some caution as the lack of sufficient time-series coverage of measures of digital technology diffusion constrains the analysis to be cross-sectional (over an average of the 2010-2016 period), implying an identification strategy that is therefore based on country-industry variability across a relatively small sample. Nonetheless, the econometric results are robust to a number of checks (e.g. for omitted variables, endogeneity and outlier influence) and lend broad support to the idea that the adoption of digital technologies by firms is supported by policy and structural factors that lift firms’ capabilities or sharpen their incentives to adopt.

9. Building capabilities within firms and in the economy at large can raise digital adoption via two key channels. First, higher organisational capital is associated with disproportionately higher digital adoption in knowledge-intensive industries relative to other industries. This is consistent with recent research demonstrating the complementarity between the productive use of ICT technologies and organisational capital, particularly managerial skills (Bloom et al., 2012a). For instance, assuming a causal relationship, our estimates imply that increasing the quality of management schools in Slovakia to best practice levels (in Belgium), or the diffusion of modern managerial practices from Greek to Danish levels, is associated with a 10 percentage point increase in the adoption rate of cloud computing in knowledge intensive industries relative to other industries.

10. Second, building capabilities within firms requires access to a deep talent pool. In this regard, three elements emerge as important for digital adoption in our estimates: the general level of ICT competence in the working age population, which among other factors is driven by the digital environment workers are exposed to, e.g. through the availability of E-Government services; the provision of specific ICT training (on the job or during job transitions; and an appropriate matching of workers’ skills to jobs. To name one example, regression results suggest that increasing the provision of ICT training to low-skilled employees from a low level (Greece) to the sample maximum (Denmark) could increase the adoption rates of cloud computing and digital front office technologies (such as customer relationship management) by around 7 percentage points in knowledge intensive industries relative to other industries. Interestingly, the marginal benefit of training for adoption is found to be twice as large for low-skilled than for high-skilled workers, suggesting that measures that encourage the training of low skilled workers are likely to entail a double dividend for productivity and inclusiveness.

11. The three sets of factors that affect market incentives (labour market flexibility, competitive pressures and the availability of risk capital), which previous research has shown to be relevant for laggard firms’ catch up to frontier productivity levels (Andrews et al., 2015), are also found to be significantly related

to the adoption of digital technologies. Encouraging the provision of venture capital (raising it from the low levels in the Czech Republic to the high levels in Denmark), for instance by eliminating fiscal bias towards debt financing or setting up public-private partnerships, could raise adoption of complex cloud computing technologies by around 8 percentage points in industries highly dependent on external finance relative to other industries. At the same time, lowering administrative burdens on start-ups (from high levels in Turkey to low levels in the Netherlands) or easing employment protection legislation (from tighter levels in Portugal to looser levels in the United Kingdom) would also stimulate adoption of a range of digital technologies in high firm (or job) turnover versus low turnover industries, though the economic magnitude of the gains would be more modest (3-5 percentage points).

12. We also find evidence of significant complementarities in the way factors affecting capabilities and incentives have a bearing for digital adoption. For instance the association between better managerial quality and higher adoption is enhanced when competitive pressures and labour market flexibility (measured respectively by the OECD indicators of product market regulation and employment protection legislation) are high.

13. Overall, the magnitude of the gains implied by our estimates, ranging from around 5 to 10 percentage point increases in adoption rates, are economically significant given that, for instance, the diffusion of cloud computing and customer relationship management varied between 10 and 60 % in our sample of countries in 2016. The estimates therefore unveil an important channel through which enhanced capabilities and incentives could help close the rising gap between frontier and laggard firms, with potentially significant effects on aggregate productivity developments.

14. The next section documents the cross-country and cross-industry variability in the adoption of digital technologies and discusses how capabilities and incentives can influence the take up of these technologies. Section 3 describes the technology data used in our empirical analysis and our proxies for capability and incentive factors. Section 4 provides illustrative evidence on the link between structural factors and rates of digital adoption, lays out the empirical framework and reports the empirical results on the influence of capabilities and incentives on key digital technologies, discussing also a number of robustness tests. Section 5 extends the analysis to examine the complementary influences of capabilities and incentives on adoption rates. Finally, we discuss policy implications and conclude.

1.1. Capabilities, incentives and adoption of digital technologies

1.1.1. Breakdown of the diffusion machine

15. Potential output growth has declined by about one percentage point per annum across the OECD since the late 1990s, which is entirely accounted for by a slowdown in labour productivity growth (Ollivaud, et al., 2016). This productivity slowdown masks a widening performance gap between more productive and less productive firms (OECD, 2015; Decker et al., 2016; Andrews et al., 2016), largely due to a slowdown in catch up by the laggards: micro-econometric evidence suggests that the OECD-wide pace of technological convergence has declined by around one-third since the late 1990s (Andrews et al., 2016).

16. A key conjecture is that this stagnation in laggard firm productivity is related to the declining capabilities or incentives for such firms to adopt best practices from the technological frontier. According to this view, the complementary intangible investments required for successful adoption of new technologies – such as managerial capital and skills – have become increasingly sophisticated, as the nature of innovation at the global frontier has shifted from one based on tangibles to one based on ideas⁴. Moreover, the market incentives for technological adoption have also weakened: A slew of micro-level evidence suggests that business dynamism has declined in many OECD countries, as witnessed by the declining propensity for high productivity firms to expand and low productivity firms to downsize (Decker et al., 2017), declining firm entry, implying less indirect pressure on incumbent firms to adopt (Criscuolo et al., 2014; Hathaway and Litan, 2014) and the increasing tendency of marginal firms to survive and consume an increasing share of the aggregate resources, despite a collapse in their relative productivity (Adalet McGowan et al., 2017a). In this context, new technologies developed at the global frontier are spreading at an increasingly fast pace across countries but diffuse increasingly slowly to all firms within any economy. Thus many existing technologies may remain unexploited by a non-trivial share of firms, a phenomenon consistent with aggregate long-run evidence provided by Comin and Mestieri (2013).⁵

1.1.2. The adoption of digital technologies still lags behind its potential

17. A wide range of digital technologies has emerged over the past decade, forming an ecosystem that holds the potential to generate significant productivity gains.⁶ Focusing on those for which comparable adoption rates are available for a large set of European countries reveals that they are unlikely to have reached widespread industrial application. Instead, many firms still seem to lack technologies considered basic by today's standards. For instance, McKinsey Global Institute (2018) estimates that overall Europe operates at only 12% of digital potential, in comparison with 18% for the United States. Figure 1 shows that while virtually all European firms are now connected to broadband internet, the diffusion of relatively more advanced tools and applications (i.e. with relatively higher adoption costs) lags behind with average diffusion rates ranging from 48% for the use of social media to 12.2% for big data analytics. Moreover, adoption rates for a

⁴ While this is typical of many new technologies, leading to the S-shaped diffusion curve (Rogers, 1997), the complementarities and complexities involved in the adoption and implementation of digital technologies are exacerbated by the move from tangible to intangible production.

⁵ Comin and Mestieri (2013) find that while adoption lags for new technologies across countries have fallen over time, there has been a divergence in long-run penetration rates once frontier firms have adopted the new technologies. For instance, they estimate that while it took an average of 45 years for the telegraph to spread across countries, the adoption lag for the cell phone technology was only 15 years. On the other hand, the cross-country differences in the penetration of new technologies have increased significantly between the earlier telephone technology and the more recent cell phone.

⁶ Among those feature prominently the Internet of Things (IoT), 3D printing or advanced robotics (OECD, 2017b), but data capturing the extent to which firms effectively use many of these frontier technologies are still scarce.

given technology greatly differ across countries and sectors. For instance, while cloud computing is prevalent in 60% of Finnish firms with 10 or more employees, the corresponding adoption rate stood at just 18% in Poland in 2016. Similarly, according to this metric, the adoption rate of enterprise resource planning systems stood at 62% of ICT producers (ISIC Rev.4 sector 61, manufacture of electronic and optical products) compared to 15% of the accommodation and catering sector (ISIC Rev. 4 sector 55-56, accommodation and food and beverage service activities).

18. The varying degrees at which digital technologies have diffused across countries and sectors seem surprising at first, considering that the marginal costs of adopting most technologies displayed above are either close to zero (e.g. for social media), or have plummeted over the past decade (e.g. for cloud computing). Taken together, the observed patterns thus suggest the presence of important structural impediments to the widespread diffusion of digital technologies.

19. One key enabler of adopting these technologies is the availability of digital infrastructures, including widely available accessible communication network and services.⁷ While most firms appear to have broadband connections, wide cross-country and cross-sector differences remain in the adoption of high-speed internet (Figure 1), which is crucial for an effective use of the digital technologies considered in this paper.⁸ Even so, differences in the availability of high-speed broadband internet can only partially account for the wide variability in the take up of digital technologies across sectors and countries, and here is where differences in capabilities and incentives enter the picture.

20. As highlighted in Figure 2, factors that shape firms' capabilities or incentives to adopt mainly affect the diffusion of digital technologies by underpinning the complementary intangible inputs required for adoption or by shaping the incentives for firms to experiment with those technologies. In addition, they can also affect adoption indirectly by influencing the productivity returns to investments in digital technologies (which would likely feed back into the original decision to adopt).

⁷ These in turn can promote both the diffusion of digital technologies and aggregate productivity growth (Égert et al., 2009; Falck and Wiederhold, 2015; Fabling and Grimes, 2016)

⁸ Here, high-speed broadband connection is defined as a download speed of at least 30 Mb/s, covering both mobile and fixed broadband. High-speed broadband connection has also been associated with positive effects on job matching and productivity (Bloom et al, 2014; Stevenson, 2008).

Figure 1. The diffusion of digital technologies is uneven across countries and industries

As a percentage of enterprises with ten or more employees, 2016

Panel A: Diffusion across countries

Panel B: Diffusion across industries (NACE Rev 2, codes 10-83)

Note: Data refers to latest available data, i.e. 2016 or 2015; unweighted averages are shown across the sample of 25 countries (Panel A), or all industries (NACE Rev 2, codes 10-83; Panel B; see Table A1 for a description of all sectors). Broadband includes both fixed and mobile connections with an advertised download rate of at least 256 kilobits per second. Enterprise resource planning systems are software-based tools that can integrate the management of internal and external information flows, from material and human resources to finance, accounting and customer relations. Cloud computing refers to ICT services used over the Internet as a set of computing resources. Cloud computing (complex) refers to a subset of relatively more complex uses of cloud computing (accounting software applications, CRM software, and computing power). Supply-chain management refers to the automatic linking of enterprises to their suppliers and/or customers applications. Customer relationship management software is used for managing a company's interactions with customers, clients, sales prospects, partners, employees and suppliers. Social media refers to applications based on Internet technology or communication platforms for connecting, creating and exchanging content on line with customers, suppliers or partners, or within the enterprise. For information on the latest available year, please refer to Table A.1. For Panel B, sector 24-25 corresponds to *Manufacture of basic metals & fabricated metal products excluding machines & equipment*; sector 26 to *Manufacture of computer, electronic and optical products*; sector 31-33 to *Manufacture of furniture and other manufacturing; repair and installation of machinery and equipment*; sector 41-43 to *Construction services*; sector 55-56 to *Accommodation and Food and beverage service activities*; sector 58-60 to *Publishing activities; motion picture, video & television programme production, sound recording & music publishing; programming & broadcasting*; sector 61 to *Telecommunications*; and sector 62-63 to *Computer programming, consultancy and related activities, information service activities*.

Source: based on Eurostat, Digital Economy and Society (database)

Figure 2. Structural channels influencing digital adoption

21. More specifically, on the capabilities side leadership skills, up-to-date managerial practices and innovative working arrangements are a necessary condition for the successful implementation of new technologies. There is a robust positive relationship between investment in organisational capital and the returns from ICT investment (Brynjolfsson et al., 1997; Behaghel et al., 2012; Bloom et al., 2012b; Bloom and Van Reenen, 2007; Pellegrino and Zingales, 2017) and Andrews and Criscuolo (2013) find that, in sectors that are heavy users of ICT, increases in organisational capital intensity are associated with swifter productivity growth than in other sectors.

22. Widespread digital adoption also hinges on access to a talented pool of workers and continuous enhancement of their skills. The necessary pool of skilled workers includes not only ICT specialists, whose expertise is (often) fundamental to deploying and managing digital technologies, but also more broadly diffused generic ICT skills among job seekers and workers, as well as out- and on-the-job programmes to provide and maintain such skills. Finally, it is not only the level of ICT skills that is important for facilitating the adoption of digital technologies but also the way in which skills in general are matched to jobs within the firm.

23. On the incentive side, competitive pressures and ease of resource reallocation are crucial to promote adoption of leading technologies. For example, recent firm-level studies document how stronger competition resulting from international trade shocks strengthens firms' incentives to adopt better technologies (Perla et al., 2015; Bloom et al., 2011). In this regard, it is no coincidence that technology diffusion stalled most – i.e. laggard firms fell further behind the global productivity frontier – in market services that are typically more sheltered from foreign and domestic competitive pressures (Andrews et al., 2016). Beyond this, the special features of digital technologies unveiled by Brynjolfsson et al (2008) and Brynjolfsson and McAfee's (2014) – easier and faster measurement of outcomes

and experimentation and replication of ideas – highlight the importance of fluid entry/exit and resource reallocation mechanisms in incentivising digital adoption, especially since these features are mutually-reinforcing: *e.g.* the value of digital experimentation is proportionately greater if the benefits, in the event of success, can be leveraged through scaling-up.⁹

24. Key areas affecting competition, notably through the entry side, include:

- *Barriers to entry for start-up firms and to competition in services.* Low burdens on entry of new firms are likely to spur digital adoption to the extent that young firms possess a comparative advantage in commercialising new technologies (Henderson, 1993) thus placing indirect pressure on incumbent firms to adopt them.¹⁰ Given the evidence that rising difficulties in technological catch up are particularly pronounced in those services sectors where pro-competitive product market reforms were least extensive, low impediments to competition in services are also likely to promote adoption (Andrews et al., 2016). Effects of competitive pressures in service provision are amplified when services additionally feed into other sectors downstream as intermediates (Barone and Cingano, 2010; Bourlès et al., 2011).
- *Open digital markets.* As with any field of trade, open digital markets bring in greater competition benefiting final consumers and businesses through lower prices and a greater variety of products. This may facilitate the take up of digital technologies as well.

25. While these factors are also indirectly relevant on the reallocation side, other areas may more specifically promote digital adoption by facilitating the related adjustments and movements of labour and capital within and across firms:

- *Employment protection legislation.* Legislation imposing heavy or unpredictable costs on hiring and firing can slow down the reallocation process (Bassanini et al., 2009; Andrews and Cingano, 2014), thereby tending to handicap productivity-enhancing investments by firms that operate in environments subject to greater technological change, such as ICT-intensive activities (Bartelsman et al., 2009; Andrews and Criscuolo, 2013) and radical innovation more generally (Griffith and MacCartney, 2010). At the same time, a reasonable degree of employment protection is also likely to aid digital adoption to the extent that it raises worker commitment and firm's incentives to invest in firm-specific human capital (Autor, 2003b; Wasmer, 2006).
- *The depth of risk capital markets.* Venture capitalists can help bridge the financing gap that arises from the fact that early adopters (often young

⁹ On the other hand, rapid upscaling due to increasing returns (or network effects) of digital technologies may reduce incentives to innovate via winner-take-most phenomena (Guellec and Paunov, 2017).

¹⁰ A long literature demonstrates the adverse effects of policy-induced barriers on firm entry (Klapper et al., 2006; Ciccone and Papaioannou, 2007) and more efficient technological adoption (Parente and Prescott, 1999; Andrews et al., 2015).

firms) lack internal funds and a track record to signal their “quality” to investors (Hall and Lerner, 2009). Thus, deep risk capital markets boost firm entry and the ability of successful new entrants to grow. Previous research has shown that cross-country differences in the availability of risk capital are significant and are positively related to the speed of technological diffusion (Saia et al, 2015; Andrews et al., 2015).

- *R&D fiscal incentives.* Promoting experimentation with new products, processes and business models through R&D tax breaks could encourage investment in digital technologies (Andrews and Criscuolo, 2013), thus affecting adoption rates directly, and indirectly through heightened competitive pressure. However, optimal effectiveness of such policies relies on the presence of complementary policies, notably targeting the exit or restructuring of low-potential incumbent firms, to ensure the availability of R&D resources (i.e. skilled labour) for innovative incumbents and entrants (Acemoglu et al., 2013).
- *Insolvency regimes.* Since the payoffs from investments in new technologies are often highly uncertain, insolvency regimes may bear on incentives for digital adoption by raising barriers to restructuring or exit of firms in the event of technological failure. As shown by Adalet McGowan et al. (2017b), low costs of scaling down, divest or exit accelerate catch up of laggard firms, arguably by incentivising experimentation and freeing up resources to underpin digital uptake by successful firms.

26. While the stylised framework in Figure 2 implies that market incentives affect digital adoption by encouraging experimentation and easing reallocation, they may also operate via the capabilities block. For instance, skill mismatch tends to be higher in countries with stringent product and labour market regulations and weaker insolvency regimes (Adalet McGowan and Andrews, 2015b). Moreover, stringent hiring and firing rules are found to thwart the ability of managers to reduce skill mismatch for any given level of managerial quality (Adalet McGowan and Andrews, 2015b), possibly reflecting excessive protection for incumbent workers in a firm, who might not be the best match for their job. Also, by imposing stronger market discipline, competition ignited by product market reforms can encourage stakeholders to improve managerial capital (e.g. by hiring better managers) and put pressure on management to improve their performance.

1.2. The data on digital technologies, capabilities and incentives

1.2.1. Indicators of digital technology adoption

27. The data on digital technology usage are drawn from the Eurostat “community survey on ICT usage and e-commerce in enterprises” and have country, industry and time dimensions. The survey provides a compilation of data on the use of information and communication technology, the internet, e-government, e-business and e-commerce in enterprises with more than 10 employees. It covers all members and accession countries of the European Union in 25 industries of the non-farm business sector (NACE Rev 2, codes 10-83) on an annual basis since 2002. However, since most of the capability and incentive variables used in our analysis are only available for OECD countries, the sample is limited to a subset of 25 OECD countries, members of the EU and Turkey. To our

best knowledge, this dataset is the only source of comparable cross-country data on digital adoption rates at the sectoral level.

28. Our analysis focuses on a sub-set of indicators selected from a list of several hundred variables available in the Eurostat dataset. The selection of technologies was based on their potential complementarity, their expected within-firm productivity-enhancing effects and their potential to diffuse these productivity benefits across firms due to spillovers.¹¹ Indeed, the aggregate benefits of some of these technologies (such as front and back office applications) can be boosted by network effects as they diffuse across firms along supply chains.¹² An additional selection criterion was to maximise cross-country, cross-industry coverage.

29. As a result, the empirical analysis covers two broad digital technologies: cloud computing (CC) and front or back office applications. We distinguish between standard and advanced cloud computing (complex CC) and between front office integration, i.e. customer relationship management (CRM), and back office integration, i.e. enterprise resource planning (ERP) (see Annex D for a detailed description of each technology). In addition, given the importance of high-speed broadband internet for the take up of these digital technologies, throughout the analysis we control for differences in the availability of this key infrastructure across countries and industries. We refrain from considering adoption of high-speed broadband internet as an outcome variable as adoption rates recorded in the Eurostat dataset most likely reflect both demand and supply factors, related to government subsidisation or outright broadband roll-out schemes, which are difficult to disentangle.¹³

30. It is worth noting that many technologies should not be considered in isolation. The emergence of CC, for instance, has drastically changed the IT landscape as it enables a much wider range of firms to apply other technologies (e.g. CRM and ERP systems) which previously required financial and human resources out of reach for many businesses. However, even the emergence of such new technologies cannot entirely overcome the features inherent in some of them – such as the complexity of ERP systems – which prevent their wider dissemination.¹⁴ Correlations across use of different digital technologies are thus not as high as one might expect (see Table A.8).

¹¹ Social media were not included in the analysis as their relevance for productivity is not clear. The adoption rates of other technologies have scarce variability across countries and industries.

¹² Hard evidence on these firm-level effects is scarce and often confined to US data, not least due to the sensitive nature of the information necessary for the investigation. Gal et al. (forthcoming) explores productivity spillovers by the same technologies in a EU context.

¹³ Unfortunately cross-country data isolating supply of broadband high-speed internet (such as in <https://data.europa.eu/euodp/data/dataset/DpWNLE4HUdjQte15bq0tRQ>) are not available at the industry level.

¹⁴ ERP is only really warranted when the business is large and complex. As a consequence, significant growth in “open source” ERP has occurred, where SMEs are the main beneficiaries. It is unclear to what extent this is reflected in the Eurostat data.

31. Given the unbalanced nature of the Eurostat survey on ICT usage (with differing period coverage across countries – see Annex A) and the one-off nature of many of the structural and policy indicators, our analysis does not have a time-series dimension. Instead, average country-industry values are taken over the sample period 2010-2016. This choice is corroborated by the observation that, within each country-industry cell, variability over time was limited over the period considered (Table A.4). To test for possible averaging bias we also performed cross-section regressions for 2014, a year in which both the technology and structural variables have virtually complete coverage. The resulting cross-sectional samples therefore cover variation across 25 countries and 25 industries.

1.2.2. Capabilities and incentives

32. We use several indicators to measure cross-country differences in capabilities and incentives. As shown in Table 1 and more in detail in Annex A, there is wide variability across countries in these indicators. Details on their definition, sources and cross-country patterns are provided below.

Table 1. Summary statistics of policy and structural factors

		Obs	Mean	Std. Dev.	Min	Max
Capabilities						
I. Organisational capital	Quality of Management school	626	4.883414	0.716024	3.687408	6.099314
	High performance work practices	500	26.05715	9.044642	10.17509	41.6223
II. Skilled labour	Percentage of adults with no ICT skills	425	20.15593	11.16819	7.243739	43.25481
	Lifelong learning	425	50.72941	12.42818	24.3	66.8
	Percentage of low skilled in training	450	35.06356	11.61629	15.84475	51.69505
	Percentage of high skilled in training	450	63.76499	13.37589	31.32726	80.72747
	E-Government	551	55.817.1	17.1	24.1	85
III. Allocation of talent	Skill mismatch	525	25.57619	5.604652	18.1	38.3
Incentives						
I. Entry and competition	Administrative barriers to start-ups	630	2.00624	0.479206	1.121914	3.080247
	Barriers in services sectors	630	3.480308	0.67593	1.365741	4.615741
	Digital trade restrictions	626	0.2152077	0.0634429	0.11	0.38
II. Exit and reallocation	EPL	625	2.529961	0.343966	1.721089	3.204082
	Venture Capital	401	0.0311	0.020665	0.002556	0.075
	Tax incentives	551	0.7306	0.07	0	0.26
	Insolvency regimes	550	0.486888	0.118902	0.130769	0.7

Note: This table only presents summary statistics for the structural and policy indicators. More details on all variables used in the empirical analysis are in Annex A.

Capabilities

33. To proxy for cross-country differences in managerial practices, we adopt two indicators, which crucially are available for a large number of countries. First, the quality of management schools – sourced from the Global Competitiveness Report of the World Economic Forum – captures the quality of education future

managers enjoy in dedicated schools.¹⁵ Second, we exploit an indicator of the share of workers involved in high performance work practices (HPWP) within firms, sourced from the OECD Programme for the International Assessment of Adult Competencies (PIAAC). Both indicators show significant variability of managerial quality across countries (Figure A.3.), with HPWP more spread out in Nordic and Anglo-Saxon countries than elsewhere.¹⁶

34. The precondition for acquiring digital skills is mastering generic skills (literacy, numeracy, and problem-solving), which provide a basis for learning fast-changing technology-specific skills (OECD, 2016a), but people's exposure to ICT is also essential. Data on the share of adults with ICT experience from the OECD PIAAC, which we use as an indicator of generic ICT skills, indeed show that in many countries a significant portion of the working age population (from around 20 per cent in Australia to over 40 per cent in Poland) still lacked such basic experience in 2012 (Figure A.5, Panel A).¹⁷ Five years later, 42% of individuals using office productivity software – i.e. “use word processors” and “use spreadsheets” – on a daily basis still report insufficient skills to use these technologies effectively (OECD, 2017b).

35. Where people integrate digital technologies into their daily life, it is likely they will encounter less difficulties in adapting to similar technologies in different contexts (e.g. at work) and that they take a more open stance towards new technologies more generally. We measure this kind of exposure to digital technologies with an indicator of e-government drawn from the OECD Science, Technology and Industry Scoreboard (2017). The use of e-government is still quite unevenly developed across Europe, with 85% of Iceland's population using public services online whereas Italy still stood at 24% in 2016 (Figure A.4).

36. Another important indicator is the share of workers involved in on-the-job training. On-the-job training aimed at enhancing ICT skills is particularly important for non-ICT workers, who are often low-skilled. Eurostat data suggests that ICT training to non-ICT workers goes along with the hiring of ICT specialists, pointing to the strong complementarities in intangible investments that are set in motion by the adoption of new technologies. However, as illustrated in Figure A.5 (Panel B),

¹⁵ Almost identical results are obtained using the 2012 WEF indicator capturing responses to the question “In your country, who holds senior management positions? [1= usually relatives or friends without regard to merit; 7=mostly professional managers chosen for merit and qualifications]”. Admittedly, a low quality of management schools can be compensated by attracting foreign-trained managers, e.g. via favourable tax regimes. However, this is likely to affect only a minority of large firms in the economy.

¹⁶ This indicator places particular emphasis on incentive systems – including bonus payments, training opportunities and flexible working hours – and the way work is organised, gauged by the prevalence of team work, autonomy, task discretion, mentoring, job rotation and the application of new learning (OECD, 2016b). While the prevalence of these practices may be also influenced by occupational structure, this is unlikely to matter in our sample of relatively homogeneous countries, and can be controlled for in regressions via fixed effects.

¹⁷ Digging deeper, the data reveal that most commonly, people falling into this category were aged 55-65, people with less than an upper-secondary level of education and people on semi-skilled occupations (OECD, 2012).

there are wide cross-country differences in the participation of workers in generic training programmes, let alone ICT-specific ones, across OECD countries. The dispersion is especially wide for the low skilled who are typically less involved in training. Indeed, only a minority of the low skilled workers take the opportunity of training offered at work, despite existing legal provisions (in most EU countries) for adults to take training leave (EC, 2017b).

37. Given the wide variability in the ability of OECD economies to efficiently allocate skills to jobs and the consequences of mismatch for productivity (Adalet McGowan et al., 2015a), it is likely that cross-country differences in adoption rates partly reflect differences in skill mismatch. We therefore test this hypothesis in the empirical analysis using the indicator of mismatch proposed by Adalet McGowan and Andrews (2015a).¹⁸ As shown in Adalet McGowan and Andrews (2015b), this measure of mismatch is affected by a number of policies, including lifelong learning as it helps to update or acquire specific and transversal skills needed by employers.

Incentives

38. On the entry side, we measure administrative burdens on startups and barriers to entry in competitive services with the corresponding indicators from the OECD Product Market Regulation dataset (OECD, 2018a). While according to these indicators the remaining cross-country differences in administrative burdens on start-up firms are relatively modest, a wider dispersion in approaches persists in the regulation of entry in services even within the EU Single Market (Figure A.6, Panel A). The extent to which countries obstruct digital trade is captured by The European Centre for Internal Political Economy (ECIPE) Digital Trade Restrictiveness Index (DTRI) (Figure A.10), which covers tariffs on digital products, restrictions on digital services and investments, restrictions on the movement of data, and restrictions on e-commerce.¹⁹

39. On the reallocation side, the ability to reshuffle the labour force, raise capital, invest in or divest from firms that experiment with new technologies are proxied by: (i) the OECD indicator of employment protection legislation (OECD, 2018b) (Figure A.7), which records procedures and safeguards for the hiring and firing of workers on both temporary and permanent contracts; (ii) the share of venture capital in GDP as recorded by Eurostat (2018) (Figure A.8), which is a measure of the depth of the risk capital market; (iii) the extent of indirect support to

¹⁸ The indicator combines objective criteria (performance on PIAAC scores relative to average scores of workers performing specific tasks) and subjective criteria (replies to questions concerning the perceived fit in those tasks) to measure the percentage of workers who are either over- or under-skilled. Over-skilling is far more common across all countries, with rates on average two and a half times higher than for under-skilling. See Adalet McGowan and Andrews (2015) for details.

¹⁹ Conceptually, the index is clustered around four large areas: (1) fiscal restrictions, (2) establishment restrictions, (3) restrictions on data and (4) trading restrictions (ECIPE, 2018). Restrictions on the movement of data also depend on data protection regulations, which are common in many regions (see Annex C for Europe), but for which comparative cross-country data with sufficient variability over the countries covered in our study does not exist.

R&D through tax incentives reported in OECD (2018c) (Figure A.9); and (iv) the OECD indicator of insolvency regimes (Adalet McGowan et al., 2017b) (Figure A.6, Panel B), which captures the barriers to the exit or restructuring of failing firms embedded in such regimes.

1.3. The influence of capabilities and incentives on digital adoption

1.3.1. Some suggestive evidence

40. Access to reliable and fast broadband connections constitutes the backbone of a digital society and economy. Among the technologies considered in this analysis, none would function effectively without the internet²⁰. Yet, all connections are not equal. Given the growing volumes of data transferred – not least to store data and software on ‘the cloud’ – the need for broadband connections with speeds greater than at least 30 Mbps has risen significantly, pointing to a strong complementarity between high-speed broadband connection and digital adoption. Using kernel densities of adoption rates at different usage levels of high-speed broadband internet, Figure 2 shows that the percentage of firms adopting digital technologies is much higher in countries and industries that have above-average access to high-speed broadband, almost double that when such access is below average for the median country-industry observation. Formally testing for the link between high-speed connections and digital adoption rates – where we control for unobserved country and industry specific factors – confirms this finding (Table A.6).

Figure 2. Use of high-speed broadband (>30 Mbit/s) is associated with higher digital

Note: Average adoption rate across 4 technologies (ERP, CRM, Cloud Computing, Cloud Computing complex for a sample of 25 countries and 25 sectors (see Appendix 1 for more details).

Source: Authors' calculations, based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017.

²⁰ While ERP and CRM system could operate within establishments without access to internet, their cost-effectiveness and efficiency-enhancing potential only fully unfolds over the web.

41. Despite being a critical premise for the adoption of digital technologies, the availability (or lack) of high-speed broadband connections cannot fully explain cross-country differences in adoption rates. As argued in previous sections, adoption rates are also likely to be affected by structural settings that enhance complementary human capital (*capabilities*) or business dynamism (*incentives*). Illustrative evidence of this link is provided in Figure 3 by comparing kernel densities of digital adoption rates for selected digital technologies across country-industry observations with less and more favourable capability and incentive conditions.

42. For instance, adoption of complex CC across industries appears to be higher in countries that have an above average level of ICT training for non-ICT workers and lower barriers to competition in services sectors. This is consistent with the strong complementarity between digital technologies and skills as well as the presumed effect of pro-competition policies – which promote business dynamism and market discipline – on the propensity to adopt.

43. Clearly, this preliminary evidence needs to be verified by multivariate regression analysis controlling for country and industry characteristics that may affect digital adoption, independent of structural and policy settings, as all these phenomena could be driven by common factors that are omitted in these simple bivariate densities, such as for instance industry structure (that tilts production towards ICT-intensive sectors requiring education towards STEM areas).

Figure 3. Structural policies and the diffusion of complex cloud computing

Note: This graph shows the distribution of cloud computing adoption rates for country-industry cells with a high/low (i.e. above/below in-sample averages of) percentage of firms providing ICT training to their employees (Panel A), and high/low barriers to services sectors (Panel B) respectively, for a sample of 25 countries and sectors (see Appendix 1 for a description of the dataset).

Source: OECD, based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017.

1.3.2. Empirical approach

44. To infer how policies can influence the diffusion of digital technologies via their effect on firms' capabilities and incentives to adopt, we apply the approach

popularized by Rajan and Zingales (1998). The advantage of this approach lies in its ability to identify the link between country-wide factors and adoption rates by relying on variability at the country-industry level. The lack of within-country variability prevalent for most structural and policy variables is overcome by including an interaction term between the country-level variable and a relevant sectoral exposure variable.

45. This approach is based on the idea that some industries (i.e. the treatment group) have a ‘naturally’ higher exposure to a given structural or policy factor than other industries (i.e. the control group). The key hypothesis is that industries in the treatment group should be disproportionately more affected than other industries by a change in the relevant policy. The effect of treatment versus control is estimated via the interaction of the structural or policy variable of interest with the corresponding industry exposure variable. At the same time, omitted factors at the country or industry level are accounted for by including fixed effects. For instance, differences in digital adoption rates may arise due to the invariable characteristics of a country (e.g. openness to trade and investment or domestic market size) or inherent technological differences across industries. Despite the fixed effects the causality of the inferred linkages does not necessarily follow due to the possible influence of confounding factors and endogeneity issues. Therefore, we perform a number of robustness checks and instrumentations to account for omitted variable and reverse causality (see below).

46. We based the choice of the exposure variables on four key sets of assumptions, which have been exploited in a range of recent analyses:²¹

- industries that are intrinsically more knowledge intensive – measured as the share of labour compensation for personnel with tertiary education – are more sensitive to differences in managerial quality and the level of workers’ skills;
- industries that experience higher firm (and job) turnover for technological reasons (e.g. more atomistic and fragmented markets or higher rates of innovation) – measured as the sum of firm entry and exit rates – are more sensitive to barriers to the entry of firms or the adjustment of the workforce;
- industries that are more dependent on external finance – measured as in Rajan-Zingales (1998) – are more sensitive to differences in the availability of private equity and the efficiency of insolvency regimes, since greater reliance on external creditors increases the likelihood of having to go through a formal insolvency process; and
- industries that are more reliant on intermediate inputs from the computer services sectors (ISIC Rev 4. Sector 72, “Computer and related activities”) as a share of total inputs, are likely more sensitive to differences in the openness of markets for digital products and services.

²¹ For instance, see Andrews et al. (2015) for knowledge intensity; Andrews and Cingano (2014) for firm turnover; and Adalet McGowan et al. (2017a) for external finance dependency.

47. Industry-level exposure variables are sourced from a large literature exploiting the same framework to explore the impact of structural factors and policies on economic outcomes (see Annex A for a detailed description of each variable and their sources).²² To the extent that the United States can be considered as a relatively frictionless and highly diversified economy and in keeping with a vast number of studies using the same sectoral diff-in-diff approach, the exposure variables are computed from US data. This also avoids in-sample issues of endogeneity of the exposure variables, since the United States is not covered by the analysis.

48. By construction, this approach does not provide an estimate of the *average* effect of the policy of interest. Rather, identification will be obtained comparing the *differential* adoption rates between highly and marginally exposed industries in countries with different levels of a given structural or policy factor.

49. The resulting baseline specification is as follows:

$$Adopt_{c,s}^j = \alpha + \beta_1 BB_{c,s} + \beta_2 Pol_c * Exp_s + \delta_c + \delta_s + \varepsilon_{c,s}, \text{ where}$$

- *Adopt* is the percentage of firms with ≥ 10 employees that have adopted digital technology *j* in industry *s* and country *c* averaged over the period 2010-16 (contingent on data availability)
- *BB* is the percentage of firms with ≥ 10 employees with a broadband connection > 30 Mb/s averaged over the same period
- *Pol* refers to different national capability and incentive factors that may affect the propensity to adopt digital technologies
- *Exp* is the industry exposure to these factors, i.e. ‘natural’ firm turnover, external finance dependency, knowledge intensity or share of computer services in total intermediate inputs; and
- δ_c and δ_s are country and industry fixed effects

50. As discussed in the previous section, we consider a number of proxies for capability and incentive factors, all of them country-wide. Table 2 lists these proxies and the industry-level exposure variables they are associated with in regressions. Further details on variable definitions and sources are provided in Annex A.

51. We assess the sensitivity and robustness of the results in a number of ways. First, we try to account for the correlation among outcome variables using the first principal component of the four adoption variables of interest as a dependent variable (Table 3; Table 4).²³ This also allows us to gauge the overall effect of the

²² Knowledge intensity by industry is drawn from OECD (2013a), firm turnover by industry is drawn from Bartelsman et al. (2009), dependence on external finance by industry from Rajan and Zingales (1998), and the share of intermediate inputs from the computer services sectors is constructed based on OECD Input-Output tables.

²³ However, identical results are also found when the first principal component of the wider set of technologies shown in Figure 2 is used instead.

various capability and incentive factors on adoption. As all dependent variables stem from the same database, it is plausible to assume that the error structures of the five models are not mutually independent. We thus further estimate the model in a system of Seemingly Unrelated Regressions (SURs) following the method developed by Zellner (1962).

52. Second, we use the first principal component of all capability factors as a regressor to account for the strong correlation among some of the organisational and human capital variables, which prevents their joint inclusion in regressions due to multicollinearity (Table 3).

53. Third, we check whether the results are robust to changes in the exposure variables. To this end, we replace the knowledge intensity exposure variable with the sectoral share of high routine-tasks (Marcolin et al., 2016) – that is significantly but not perfectly correlated with our measure of knowledge intensity (see Figure B.1) – and also interact EPL with layoff rates (defined as the percentage ratio of annual layoffs to total employment) instead of firm turnover (see Table B.2). Moreover, we demonstrate the validity of knowledge intensity as exposure variable by replacing it with an unrelated measure, here chosen to be firm turnover (Table B.6).

54. Fourth, to account for country-level confounding factors that may affect adoption differently across industries (and therefore are not captured by our fixed effects), we re-run the regressions adding an interaction of the exposure variables with GDP per capita (which is a catch-all variable; Table B.2). To further support the interpretation of our results, we also perform placebo tests in which we replace our measure of capabilities with one correlated with it, but that is unlikely to disproportionately affect digital adoption in knowledge intensive sectors (the relevant exposure variable).

55. Fifth, to account for potential endogeneity between capabilities and adoption, we instrument each capability measure by the average of a country's neighbours (Table B.7).²⁴ On the incentive side, we also re-estimate our baseline regression instrumenting product market regulations with indicators of legal origin following Andrews and Cingano (2014). This helps addressing potential political economy concerns, as one could argue that inefficient (and weakly-adopting) incumbent firms in sectors with higher natural turnover could be more vocal in lobbying for protection in the form of higher policy-induced entry costs for start-ups and in particular for services providers than firms in sectors with lower natural turnover (Table B.8).

56. Finally, we check for the possible influence of outliers on the results by running regressions that drop one country or one industry at a time (Table B.9 and Table B.10).

²⁴ See Andrews et al. (2016) for a similar approach to instrumentation.

Table 2. Proxies for capability and incentive factors

	Proxy variable	Source of proxy variable	Exposure variable
Capabilities			
Organisational capital	Quality of management schools	World Economic Forum	Knowledge intensity
	High performance work practices (HPWP)	OECD Programme for the International Assessment of Adult Competencies (PIAAC)	Knowledge intensity
Skilled labour	Percentage of adults with no ICT skills	OECD Programme for the International Assessment of Adult Competencies (PIAAC)	Knowledge intensity
	The share of (low and high-skilled) workers receiving training	OECD Programme for the International Assessment of Adult Competencies (PIAAC)	Knowledge intensity
	The share of adults participating in lifelong learning	OECD Programme for the International Assessment of Adult Competencies (PIAAC)	Knowledge intensity
	E-Government	OECD Science, Technology and Industry Scoreboard 2017	Knowledge intensity
Allocation of talent	Skill mismatch	Adalet McGowan and Andrews (2015) based on the OECD Programme for the International Assessment of Adult Competencies (PIAAC)	Knowledge intensity
Incentives			
Entry and competition	Administrative burdens on start-ups	OECD Product Market Regulation Index	Firm turnover
	Barriers to entry in services	OECD Product Market Regulation Index	Firm turnover
	Digital Trade Restrictiveness Index	European Centre for International Political Economy	Share of computer service (ISIC Rev4 sector C72: Computer and related activities) purchases, in total purchases of intermediates.
Exit and reallocation	The OECD indicator of employment protect legislation (EPL)	OECD Indicators of Employment Protection	Firm turnover
	The share of venture capital in GDP	Eurostat	External financial dependency
	Indirect government support through R&D tax incentives	OECD Science, Technology and Industry Scoreboard 2015 - © OECD 2015	Knowledge intensity
	OECD indicator of the efficiency of insolvency regimes	OECD Insolvency Regime Indicator	External financial dependency

Note: Please refer to Annex 1 for more detailed information.

1.3.3. Results

57. We estimate three versions of our baseline digital adoption model. First we test the influence of capability and incentive factors separately and one by one (Table 3, Table 4). Then we test the joint influence of pairs of capability and incentive factors (Table 5). Last, for a reduced set of variables, we check for potential policy complementarities between both sets of structural factors (Table 6), which involves adding an interaction of capabilities and incentive indicators to the model. Multicollinearity among large sets of interaction terms (often with the same exposure variable) makes it difficult to go beyond these three types of regressions.

Given that results from the pairwise regressions provide the most conservative estimates of the effects of capability and incentive factors on digital adoption, we use them to infer the economic significance of our estimates.

58. Since the data on adoption rates are drawn from the same survey and that different technologies are likely to be complementary, there could be losses in efficiency in ignoring the possibility that errors may not be mutually independent across regressions. To account for this, we also ran systems of seemingly unrelated regressions (SUR) of the adoption rates of all digital technologies on each of the capability and incentive variables, but the results remained unchanged.²⁵

59. It should be noted at the outset that high-speed broadband penetration has in all cases a strongly significant and positive association with adoption rates of all the technologies considered. Given that this variable measures both demand and supply factors, no quantitative implications for the effects on adoption of the roll out of high-speed broadband Internet can be inferred from the estimates. However, the results strongly confirm the expected complementarity between high-speed broadband and the other digital technologies, underscoring the need for ubiquitous broadband deployment.

4.3.1 The influence of capabilities on digital adoption

60. Taking into account the correlation across indicators of capabilities, Table 3 first reports the results of difference-in-difference regressions for the first principal component of the capabilities indicators used in our analysis. Overall, we find the latter to be strongly and positively associated with all digital technologies with the exception of digital adoption of ERP, whose regression coefficients are often insignificant. All other digital adoption variables display the expected significant and positive association. Unsurprisingly, the same results are found when we summarise digital technologies by their first principal component (last column).²⁶

61. Turning to the individual capabilities, results suggest that both the quality of organisational capital and the availability and allocation of talents are associated with significantly higher digital adoption rates in knowledge-intensive industries relative to other industries. Specifically, the quality of management (proxied by the share of workers involved in management practices that stimulate employee and organisational performance and the training received by future managers in management schools), is associated with higher CRM and cloud computing adoption (both CC and complex CC). These findings confirm that qualified firm management is a necessary complementary investment to the adoption of digital technologies in order to initiate and guide the adoption process.

62. Moreover, adoption rates of CRM and cloud computing are significantly and positively associated with workers' general skills, the provision of e-government services, specific ICT competences and participation in lifelong learning and on the job training. Thus implementing digital change within a firm requires workers with a multiplicity of skills, which they continuously develop in order to keep pace with the fast changing technological landscape.

²⁵ SUR results are available from the authors upon request.

²⁶ As already mentioned, to some extent this reflects co-variation of these variables across the country-industry dimension.

63. Digging deeper, the results suggest training to be especially effective for low-skilled workers, as the complementarity with adoption is significantly higher for investment in training for low skilled than high skilled (Figure 4). Increasing the percentage of low-skilled workers that receive training by one standard deviation is associated with a 3 percentage points increase in the share of firms adopting CRM or cloud computing systems in knowledge-intensive relative to other industries, compared to a 1.7 percentage point increase from the same increase in training for workers with a high formal education level. While upgrading ICT skills of high-skilled staff remains an important driver of ICT adoption, these findings suggest that the attainment of sound levels of basic ICT skills (e.g. access information online or use software) by low-skilled workers is even more beneficial to the deployment of digital technologies. Thus, investing in training of low-skilled workers not only helps raising their productivity and wages, making the labour market more inclusive, but also holds the potential to increase aggregate productivity via faster adoption of advanced technologies.

Figure 4. The complementarity of training with adoption is stronger for the low-skilled

The differential association of training provided to high and low skilled workers with the percentage of firms adopting CRM and cloud computing systems

Note: This figure shows the ceteris paribus impact of an increase of a one standard deviation (11% for low-skilled, 13% for high-skilled) of the percentage of high/low-skilled workers having participated in formal training on the percentage of firms adopting CRM/Cloud Computing technologies between industries with a high or low knowledge intensity. Calculations are based on estimates from Table 3.

Source: OECD, based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017

64. Finally, not only the level of skills but also the way they are allocated matters for digital adoption. Regression estimates suggest that lower skill mismatch is associated with disproportionately higher rates of adoption of CRM and cloud computing in knowledge-intensive sectors compared to other sectors. Thus, digital adoption critically depends on the ability of an economy to avoid wasting talents and allocate workers to the jobs they are best suited for, especially as firms draw from a scarce and fixed pool of skilled labour in the short to medium term. In turn, this ability has been shown to be strongly associated with a range of policies in labour and product markets (Adalet McGowan and Andrews, 2017).

Table 3. Capabilities and digital adoption

Dependent variable: percentage of firms >10 employees adopting the digital technology

	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1 st principal component
A. Capabilities					
Principal Component Analysis					
1 st principal component (skills) x knowledge intensity	-0.00893	0.0330***	0.0448***	0.0578***	0.535***
High-speed broadband access (>30Mbit/s)	0.269***	0.316***	0.247***	0.146**	3.172***
Observations	246	246	248	227	223
I. Organisational capital					
Quality of Management school x knowledge intensity	-0.0265	0.114***	0.171***	0.163***	1.650***
High-speed broadband access (>30Mbit/s)	0.217***	0.235***	0.169***	0.0991**	2.490***
Observations	477	477	456	435	429
High performance work practices x knowledge intensity	-0.00219	0.00987***	0.00552**	0.00857***	0.0807***
High-speed broadband access (>30Mbit/s)	0.353***	0.251***	0.171**	0.117**	2.797***
Observations	384	385	364	343	338
II. Skilled labour					
Percentage of adults with no ICT skills x knowledge intensity	0.00177	-0.00697***	-0.00850***	-0.0102***	-0.101***
High-speed broadband access (>30Mbit/s)	0.352***	0.238***	0.197***	0.106**	2.807***
Observations	321	321	322	301	
Low skilled in training x knowledge intensity	1.35e-05	0.00746***	0.00612***	0.00974***	0.0897***
High-speed broadband access (>30Mbit/s)	0.314***	0.299***	0.205***	0.115**	2.986***
Observations	353	354	334	313	308
High skilled in training x knowledge intensity	-0.000407	0.00497***	0.00357**	0.00753***	0.0654***
High-speed broadband access (>30Mbit/s)	0.318***	0.310***	0.220***	0.120**	3.082***
Observations	353	354	334	313	308
Lifelong learning x knowledge intensity	-0.000777	0.00706***	0.00673***	0.00935***	0.0897***
High-speed broadband access (>30Mbit/s)	0.351***	0.218***	0.183**	0.0803	2.570***
Observations	321	321	322	301	297
E-Government x knowledge intensity	0.000174	0.00509***	0.00514***	0.00466***	0.0550***
High-speed broadband access (>30Mbit/s)	0.191***	0.233***	0.148**	0.115**	2.384***
Observations	411	411	390	369	363
III. Allocation of talent					
Skill mismatch x knowledge intensity	0.00133	-0.0157***	-0.00863***	-0.00833***	-0.112***
High-speed broadband access (>30Mbit/s)	0.307***	0.252***	0.183***	0.138***	2.805***
Observations	406	407	386	365	360

Note: This tables reports baseline estimates of the baseline equation where each digital technology is regressed on the percentage of firms using high-speed broadband connections in a given country-industry cell, one policy variable of interest interacted with industry knowledge intensity and country and industry fixed effects. The last column shows results for the 1st principal component of the 4 technologies. Regressions are based on a country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016. ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Source: OECD calculations based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017

4.3.2 Factors affecting the incentives to adopt

65. Estimates of the influence of our proxies for market incentives on adoption rates are reported in Table 4. Results for the first principal component of digital adoption rates suggest that there is considerable scope to spur diffusion of digital technologies via easing frictions on the reallocation process, strengthening competitive pressures and stimulating financial market development.

66. In line with our expectations, lower administrative burdens on startups are estimated to increase rates of adoption of cloud computing in industries with relatively higher turnover rates, possibly reflecting both stronger competitive pressures on incumbents and the innovative approaches of new entrants. Similar effects are found for barriers to entry in services sectors on adoption rates in the case of cloud computing and CRM. Here, stronger market incentives to adopt in service sectors (retail, business services and road freight) and easier adoption due to lower costs of intermediate inputs for other sectors that use these services could be at play. Barriers to digital trade, conceivably resulting from reduced competitive pressures and more difficult access to crucial inputs, are also found to have a negative impact on the adoption of all technologies.

67. Turning to factors of reallocation, we find that easier EPL regimes are associated with higher adoption rates across all technologies in sectors with a naturally high firm turnover (where reallocation needs are likely to be more intense) relative to low-turnover sectors. EPL being the only variable for which the estimated coefficient is significant across all technologies, the results highlight the importance of labour market adaptability for digital adoption, though more research on more granular data would be required to identify the precise channels through which these effects operate.

68. Seed and early-stage finance policies play an overall positive role for the adoption of digital technologies. Sectors more dependent on external finance experience significantly higher adoption rates of CRM systems and cloud computing relative to other sectors. When access to venture capital increases, this likely reflects easier access to finance of ventures that use these technologies, especially (but not only) for young firms. Similarly, incentives to investment in R&D appear to be associated with greater adoption of CRM and CC, perhaps suggesting complementarity between R&D activity and the ability to experiment with digital technologies.

69. Lastly, well-designed insolvency regimes (e.g. where sanctions for personal insolvency are more lenient and barriers to corporate restructuring of insolvent firms are lower) are associated with higher cloud computing adoption rates in sectors relatively more dependent on external finance. Given that this technology is especially attractive for young firms, as it allows to reach scale without incurring heavy investments in IT infrastructure, the results may reflect several factors: stronger incentives to adopt due to heightened market discipline, less risk aversion to uptake this digital technology by young entrepreneurs and also more room for new digitalised entrants as resources are released by the exit or downsizing of weak incumbents.

4.3.3 Pairwise regressions and economic significance

70. The two panels of Table 5 show the results of the adoption regressions in which capability and incentive variables are jointly and pairwise included. For simplicity, we omitted regression results obtained with the principal component of adoption rates across technologies and focus on just a subset of our indicators of ease of entry and competition and ease of exit and reallocation.²⁷ Adoption rates of each of the digital technologies are regressed on one capability and one incentive variable, while continuing to control for high-speed broadband internet uptake and country and industry fixed effects. It should be noted that the introduction of both variables simultaneously sometimes reduces drastically the number of observations due to different coverage of the capability and incentive variables, making the comparison of results in this table with previous estimates difficult. Nonetheless, given that these regressions are more demanding in terms of both degrees of freedom and variables covered, they yield the more conservative estimates on which the economic significance of structural and policy factors can be verified (see below). Indeed, as expected all estimated coefficients in the joint regressions have a tendency to become slightly smaller than in the previous one-by-one regressions, though their magnitude is quite stable across specifications.

71. On the whole, the coefficients and significance of the interactions between country-level capability variables and industry-level knowledge intensity remain little affected by their pairwise estimation with the interactions between market incentive variables and their corresponding industry exposure variables. The only exception are regressions that include venture capital, in which many of the capability variables lose significance, most probably reflecting the significant reduction in sample size associated with the use of this incentive variable.

72. Similarly, results for most of the incentive variables are little affected by the inclusion of capability variables in the regression. EPL and digital trade restrictions remain the only variables that have negative effects on rates of digital adoption of most technologies, even though significance is lost in some instances (e.g. when estimated jointly with training and lifelong learning). Administrative burdens on start-ups and barriers to entry in services maintain their negative effects on cloud computing technologies, though the effect on CC loses significance in a few cases. The availability of venture capital still has positive and significant effects on most technologies except ERP, though results lose significance when estimated jointly with e-government. Tax credits to R&D generally maintain their positive and significant effect on adoption of all technologies except ERP, but lose significance when jointly estimated with the quality of management schools. By contrast, the inefficiency of insolvency regimes maintains its negative effects on cloud computing but is now rarely significant, and therefore results for this variable are omitted from the table.

²⁷ Omitted results are similar and available from the authors upon request.

Table 4. Market incentives and digital adoption

Dependent variable: percentage of firms >10 employees adopting the digital technology

	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1 st principal component
Entry and competition					
PMR Administrative burdens on start-ups x Turnover	0.00235	-0.00158	-0.00330**	-0.00630***	-0.0473***
High-speed broadband access (>30Mbit/s)	0.209***	0.251***	0.186***	0.127***	2.685***
Observations	477	477	456	435	429
PMR Barriers in services sectors x Turnover					
High-speed broadband access (>30Mbit/s)	0.207***	0.257***	0.189***	0.129***	2.718***
Observations	477	477	456	435	429
Digital Trade Restrictiveness Index X Share of Computer services as input into sector x High-speed broadband access (>30Mbit/s)					
High-speed broadband access (>30Mbit/s)	-0.0371**	-0.0769***	-0.0323*	-0.0497**	-0.607**
Observations	477	477	456	435	429
Exit and reallocation					
Employment Protection Legislation x Turnover	-0.00556*	-0.00649***	-0.00423**	-0.00439***	-0.0648***
High-speed broadband access (>30Mbit/s)	0.225***	0.260***	0.186***	0.119***	2.669***
Observations	477	477	456	435	429
Venture Capital x Financial Dependency					
High-speed broadband access (>30Mbit/s)	-0.00253	0.526***	0.348***	0.547***	5.298***
Observations	290	289	290	270	265
Tax incentive support for BERD X Knowledge Intensity					
High-speed broadband access (>30Mbit/s)	-0.136	0.656**	0.554***	0.241	3.632
Observations	411	411	390	370	364
Insolvency Regime Rigidity x Financial Dependency					
High-speed broadband access (>30Mbit/s)	0.0211	-0.0145	-0.0482**	-0.0375**	-0.392**
Observations	419	419	398	377	371

Note: This table reports baseline estimates of the baseline equation where each digital technology is regressed on the percentage of firms using high-speed broadband connections in a given country-industry cell, one policy variable of interest interacted with the relevant exposure variable (industry firm turnover or sector dependency on external finance) and country and industry fixed effects. The last column shows results for the 1st principal component of the 4 technologies. Regressions are based on a country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016.

***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Source: OECD calculations based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017.

Table 5. The joint effects of incentives and capabilities

Pairwise regression results

ENTRY AND COMPETITION												
Incentives	Administrative barriers for start-ups x Turnover				Barriers to the services sector x Turnover				DTRI X share of comp services			
	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)
<i>Incentive</i>	0.00227	-0.00120	-0.00274*	-0.00576***	0.00142	-0.00170	-0.00184**	-0.00370***	-0.0398**	-0.0691***	-0.0334**	-0.0486**
Quality of management schools x knowledge intensity	-0.0249	0.113***	0.169***	0.160***	-0.0252	0.113***	0.170***	0.160***	-0.0346	0.101***	0.172***	0.163***
<i>Incentive</i>	0.00297	-0.00143	-0.00271	-0.00614***	0.00165	-0.00163	-0.00182*	-0.00383***	-0.0261	-0.0616***	-0.0333*	-0.0659***
High Performance Work Practices x knowledge intensity	-0.00198	0.00976***	0.00532**	0.00814***	-0.00195	0.00963***	0.00523**	0.00799***	-0.00315	0.00766***	0.00484**	0.00737***
<i>Incentive</i>	0.000410	-0.00297	-0.00322	-0.00600***	0.000707	-0.00177	-0.00185*	-0.00358***	-0.0424**	-0.0765***	-0.0356**	-0.0561***
Percentage of adults with no ICT skills x knowledge intensity	0.00175	-0.00680***	-0.00831***	-0.00990***	0.00170	-0.00677***	-0.00829***	-0.00984***	0.00216	-0.00627***	-0.00816***	-0.00942***
<i>Incentive</i>	0.00330	-0.000244	-0.00202	-0.00589***	0.00167	-0.00101	-0.00144	-0.00349***	-0.0289*	-0.0508***	-0.00923	-0.0305*
Percentage of low skilled in training x knowledge intensity	0.000191	0.00745***	0.00600***	0.00939***	0.000222	0.00733***	0.00592***	0.00928***	-0.00110	0.00555***	0.00586***	0.00883***
<i>Incentive</i>	0.00327	-0.000370	-0.00225	-0.00608***	0.00164	-0.00116	-0.00162*	-0.00362***	-0.0297*	-0.0585***	-0.0203	-0.0427**
Percentage of high skilled in training x knowledge intensity	-0.000256	0.00496***	0.00346**	0.00722***	-0.000238	0.00485***	0.00338**	0.00712***	-0.00132	0.00325*	0.00319**	0.00651***
<i>Incentive</i>	0.000502	-0.00287	-0.00328	-0.00591***	0.000756	-0.00165	-0.00183*	-0.00347***	-0.0471**	-0.0638**	-0.0225	-0.0336*
Lifelong learning x knowledge intensity	-0.000750	0.00690***	0.00654***	0.00902***	-0.000686	0.00686***	0.00650***	0.00893***	-0.00197	0.00544***	0.00616***	0.00843***
<i>Incentives</i>	0.00186	-0.00166	-0.00219	-0.00594***	0.00117	-0.00200	-0.00107	-0.00360***	-0.0490***	-0.0674***	-0.0133	-0.0333*
E-Government x knowledge intensity	0.000214	0.00505***	0.00510***	0.00456***	0.000234	0.00498***	0.00508***	0.00448***	-0.000736	0.00383***	0.00497***	0.00426***
<i>Incentive</i>	0.00323	-0.00155	-0.00273	-0.00640***	0.00166	-0.00183*	-0.00197**	-0.00400***	-0.0230	-0.0786***	-0.0410**	-0.0821***
Skill mismatch x knowledge intensity	0.00118	-0.0156***	-0.00847***	-0.00796***	0.00112	-0.0154***	-0.00835***	-0.00781***	0.00120	-0.0162***	-0.00884***	-0.00901***

DIGITAL TECHNOLOGY DIFFUSION: A MATTER OF CAPABILITIES, INCENTIVES OR BOTH?

Table 5. (continued)

REALLOCATION AND EXIT												
Incentives	Venture Capital x Financial Dependency				BERD indirect X knowledge intensity				EPL x Turnover			
	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)
<i>Incentive</i>	0.0714	0.444***	0.158	0.394***	-0.0186	0.252	0.0295	-0.306	-0.00564*	-0.00613***	-0.00380*	-0.00396***
Quality of management schools x knowledge intensity	-0.0581	0.0644	0.149***	0.120***	-0.0309	0.106***	0.162***	0.158***	-0.0282	0.112***	0.170***	0.162***
<i>Incentive</i>	0.129	0.418***	0.414***	0.595***	-0.0753	0.792***	0.705***	0.424**	-0.00515*	-0.00680***	-0.00282	-0.00342*
High Performance Work Practices x knowledge intensity	-0.00437	0.00476	-0.00199	-0.00124	-0.00220	0.00961***	0.00534**	0.00818***	-0.00241	0.00957***	0.00539**	0.00843***
<i>Incentive</i>	0.0715	0.439***	0.181	0.351***	-0.0483	0.597**	0.588***	0.117	-0.00592**	-0.00769***	-0.00318	-0.00306*
Percentage of adults with no ICT skills x knowledge intensity	0.00160	-0.00281	-0.00463**	-0.00534***	0.00207	-0.00858***	-0.00842***	-0.0102***	0.00193	-0.00677***	-0.00842***	-0.0102***
<i>Incentive</i>	0.00492	0.401***	0.235	0.327***	0.103	0.620**	0.634***	0.308	-0.00711*	-0.00589**	-0.00261	-0.00334
Percentage of low skilled in training x knowledge intensity	-5.96e-05	0.00434*	0.00358	0.00635***	-6.05e-05	0.00781***	0.00560***	0.00900***	-0.000189	0.00729***	0.00604***	0.00964***
<i>Incentive</i>	0.0724	0.541***	0.326**	0.373***	0.105	0.662**	0.660***	0.321	-0.00715*	-0.00612**	-0.00286	-0.00353
Percentage of high skilled in training x knowledge intensity	-0.00203	0.000671	0.00127	0.00554***	-0.000491	0.00499***	0.00316*	0.00682***	-0.000574	0.00482***	0.00350**	0.00744***
<i>Incentive</i>	0.0376	0.382***	0.214	0.328***	-0.0950	0.839***	0.803***	0.431**	-0.00589**	-0.00748***	-0.00306	-0.00280
Lifelong learning x knowledge intensity	-0.000609	0.00363	0.00320*	0.00508***	-0.000750	0.00806***	0.00658***	0.00884***	-0.000970	0.00682***	0.00663***	0.00926***
<i>Incentive</i>	-0.649**	0.114	0.143	0.316	-0.0646	0.651**	0.563***	0.285	-0.00418	-0.00604***	-0.00450**	-0.00433**
E-Government x knowledge intensity	0.00303	0.00522***	0.00609***	0.00566***	0.000426	0.00622***	0.00593***	0.00524***	0.000124	0.00503***	0.00509***	0.00462***
<i>Incentive</i>	0.0631	0.378***	0.279**	0.596***	-0.0403	0.534*	0.516**	0.161	-0.00494*	-0.00691***	-0.00298	-0.00368**
Skill mismatch x knowledge intensity	0.00379	-0.0121***	-0.00570	0.00250	0.00213	-0.0144***	-0.00842**	-0.0107***	0.00155	-0.0153***	-0.00849***	-0.00817***

Note: These tables show the results of the adoption regressions in which each digital technologies is regressed on a pairwise combination of capability and incentive variables interacted with the relevant exposure variable, the percentage of firms using high-speed broadband connections, and country and industry fixed effects. Regressions are based on country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016. Estimates highlighted in grey are used to create Figure 5 and Figure 6.

***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Source: OECD calculations based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017

73. To get a sense of the economic significance of the effects of structural factors and policies on the share of firms adopting digital technologies, Figure 5 and Figure 6 illustrate the findings graphically. Interpreting the estimates causally, the figures compare the effect of changes in selected structural and policy factors on digital technology adoption rates between high (i.e. at the 75th percentile distribution) and low exposed sectors (i.e. at the 25th percentile distribution). The changes are cast in terms of moving from worst to best practice in capability and incentive factors. While this approach provides some concreteness to the exercise, a caveat is that the implied changes vary across the different factors as they reflect the variability of capability and incentive conditions across countries. Consequently, comparison of the size of effects ought to be interpreted in the light of the cross-country dispersion in each of the factors (see Table 4 for details). As already mentioned, calculations are based on the most conservative estimates, accounting for both incentives and capabilities (Table 5). Effects that are statistically not significant are reported as nil.

74. In most cases, increasing capabilities from the lowest to the highest level observed in the sample would have striking effects on digital adoption rates of exposed industries. For instance, a fourfold increase in the coverage of workers involved in HPWPs (equivalent to moving from 8 percent in Greece to 40 percent in Denmark) would increase the adoption rates of these technologies by roughly 8 percentage points. Similar increases would also be observed upon promoting the use of e-government services (from Italian to Icelandic levels; Panel B) and increasing training of low-skilled workers (from Greek to Danish levels; Panel C). Slightly smaller yet sizeable effects would be obtained from reducing skill mismatch (from Greek to Polish levels).

75. To put these effects into perspective, a 10 percentage point increase is roughly equivalent to one fifth or more (depending on the technology) of the observed dispersion in diffusion rates across our sample of countries (Figure 1). Of course, the simulated changes in capabilities are sometimes very large and would take time to occur as they would require a strong and sustained effort by both public institutions and firms. However, they highlight the potential for education, training and other policies affecting skills to significantly affect the extent of technological take-up by firms over the medium term, pointing to the need to frontload their implementation.

76. The estimated gains in adoption of exposed versus non exposed industries that are implied by changes in factors that affect incentives are somewhat less spectacular but still large, especially in view of the fact that some of them (e.g. reducing administrative burdens or reforming insolvency regimes) could be implemented more rapidly and at lesser cost than those affecting capabilities. For instance, easing firm entry by reducing administrative burdens on start-ups (from the high level in Turkey to the lowest level in the Netherlands) would increase adoption rates of cloud computing by 3 to 4 percentage points, and similar increases would be obtained by lifting barriers to digital trade from high levels in Turkey to best practice in Iceland. Effects of similar size but generalised across all technologies would be obtained by easing EPL (from the relatively tight levels in Portugal to the relatively loose levels in the UK), thereby making adjustment of the workforce to meet digital change within incumbent firms easier and facilitating the entry of innovative firms. The effects simulated for financial market developments leading to an increase in the share of venture capital in GDP (from Czech to Danish levels) are much stronger, particularly as the dispersion in the availability of venture capital across countries is very wide (Table A.3).

Figure 5. Economic significance (Capabilities)**A: Increase in digital adoption rate from increasing the diffusion of HPWP to maximum level (DNK)***Differential impact between industries with high and low knowledge intensity* **B: Increase in digital adoption rate from increasing the share of citizens using e-government services to maximum level (ISL)***Differential impact between industries with high and low knowledge intensity* **C: Increase in digital adoption rate from increasing the percentage of low skilled workers in training to maximum level (DNK)***Differential impact between industries with high and low knowledge intensity* **D: Increase in digital adoption rate from bringing skill mismatch to minimum level (POL)***Differential impact between industries with high and low knowledge intensity*

Notes: These graphs show the ceteris paribus increase in digital adoption rates from increasing the diffusion of HPWP (Panel A), the percentage of low-skilled in training (Panel C), or the share of citizens using E-Government services (Panel B), or decreasing the percentage of workers with skill mismatch (Panel D) to sample minimum, between industries with a high (i.e. 75th percentile) or low (i.e. 25th percentile) knowledge intensity. Calculations are based on the most conservative estimates (i.e. smallest magnitude of most significant estimate) from Table 5. No calculations are made where estimates were consistently insignificant (e.g. ERP systems). Note that the *lowest* benefit (or increase) is reaped by countries that are close to the sample optimum, as their scope for reform is limited. By construction, the lowest/highest benefit will always be made by the same country within each panel. The average effect is represented by the circle, the 1st and 3rd quartile by the blue bar.

Figure 6. Economic significance (Incentives)

A: Increase in digital adoption rate from reducing EPL to minimum level (GBR)*Differential impact between industries with high and low firm turnover* **B: Increase in digital adoption rate from increasing the share of venture capital (as a percentage of GDP) to maximum level (DNK)***Differential impact between industries with high and low external financial dependency* **C: Increase in digital adoption rate from decreasing administrative burdens for start-ups to minimum level (NLD)***Differential impact between industries with high and low firm turnover* **D: Increase in digital adoption rate from easing barriers to digital trade to minimum level (ISL)***Differential impact between industries with a high and low share of intermediate computer services inputs*

Notes: These graphs show the ceteris paribus increase in digital adoption rates from decreasing EPL (Panel A), administrative burdens for start-ups (Panel C), and insolvency regime rigidity (Panel D) to sample minimum, or increasing the share of venture capital as a percentage of GDP (Panel B) to sample maximum, between industries with high (i.e. 75th percentile) and low (i.e. 25th percentile) turnover rates (Panel A) or external financial dependency (Panel B, C, D). Calculations are based on the most conservative estimates (i.e. smallest magnitude of most significant estimate) from Table 5. No calculations are made where estimates were consistently insignificant (e.g. ERP systems in Panel B, C, and D). Note that the *lowest* benefit (or increase) is reaped by countries that are close to the sample optimum, as their scope for reform is limited. By construction, the lowest/highest benefit will always be made by the same country within each panel. The average effect is represented by the circle, the 1st and 3rd quartile by the blue bar.

4.3.4 Robustness

77. We performed a number of robustness checks to reduce the possibility that our results could suffer from a bias affecting coefficient estimates and their interpretation, notably as a result of omitted variables and endogeneity.

78. Omitted variables can affect results both via the country-level capability and incentive variables, and via the industry-level exposure variables. While the fixed effect structure controls for omitted variables that could induce shifts at the country or sector level, they cannot control for omitted factors that could drive both the (country-level) capability or incentive variables and the (sector-level) exposure variables. To the extent that they are not captured by broadband penetration, which is the only control variable in this analysis having both dimensions, these confounding factors could be driving some of the estimated impact of the interaction term on adoption rates, which in turn could lead to overestimating the effects of capabilities or incentives on adoption.

79. To help ruling out such confounding effects we take two approaches. First, we augment our regressions with an interaction between GDP per capita and the relevant exposure variable, which should capture country-level factors that are likely to disproportionately affect exposed industries beyond capabilities or incentives. Most of our results were not substantially affected by this change in model specification, suggesting no significant omitted variable bias in coefficient estimates (Table B.2). Second, we run two placebo tests on the capability indicators, which we replace with a country's average firm size or with a measure of urban concentration. Urban concentration is correlated with country-level capabilities, due to the boosting effects of urban density on skills via synergies and spillovers (Glaeser and Resseger, 2010). Similarly, higher average firm size could indicate the presence of multinational companies, or companies more likely to be integrated in global value chains, which in turn tend to benefit from greater exposure to knowledge-spillovers (Criscuolo et al., 2016). However, there is little reason to believe that either placebo variable should per se disproportionately affect adoption in industries with different levels of knowledge intensity. As expected, regression results are not found to be statistically significant, neither in the absence, nor in the presence of the original interaction term between capabilities and knowledge intensity (Table B.3.).

80. To test the validity of our exposure variables, we replace some of them by non-perfectly correlated alternatives in interactions with the capability. For instance, as shown in Table B.5 results for capabilities indicators are robust to replacing knowledge intensity with the sectoral share of high-routine tasks (in the US) as an exposure variable. This is reassuring concerning the nature of the effect captured by the interaction term: differential effects of capabilities across industries reflect the fact that organisational and human capital requirements for digital adoption are particularly strong in industries that are intensive in tasks that are complementary to those technologies. Similarly, results for EPL hold robust when its effect is on adoption rates is measured in sectors with high relative to low job layoff rates instead of firm turnover rates (see Table B.4.), highlighting, once again, the importance of labour market adaptability for the diffusion of digital technologies.

81. Next, we rule out the possibility of spurious correlation between knowledge intensity and the dependent variable by replacing it with firm turnover, which represents an uncorrelated alternative exposure variable. Results in Table 6 show that, indeed, using this specification the significance of capabilities on digital adoption fades. However,

when both interaction terms are included, the significance of capabilities interacted with knowledge intensity persists, supporting the interpretation of our baseline results.

82. While endogeneity and reverse causality are less likely to be a concern in a Rajan-Zingales specification due to the difference-in-difference framework and the fact that the policy variables in this study do not vary at the industry level, one may still suspect the presence of reverse causality. After all, country level investment in organisational capital or skills could also be caused by the adoption of digital technologies rather than the opposite. This would tend to inflate the coefficient estimates, as well as weaken the case for advocating changes in capability and incentive factors to boost adoption. To address this possibility, we instrument the country-specific capability variables with the average of values of the same variables in neighbouring countries (excluding the country's own value) and interact these constructs with the industry-level exposure variables (Table B.7). Again, the baseline results are not qualitatively affected by this change in variable definition, and if anything the magnitude of the estimated effects increased, suggesting that reverse causality is not likely to be a serious issue and corroborating our interpretation of the channels at work.

83. Similar reverse causality concerns could arise for incentive variables if lack of adoption would set off political economy pressures for protection of incumbents. This could be the case in countries where incumbent firms in sectors with higher natural turnover have greater lobbying power to strengthen their protection against more digitalised competitors in the form of higher policy-induced entry costs than firms in sectors with lower natural turnover. Following Andrews and Cingano (2014) we test for the robustness of our results using an instrumental variable approach, where variables of product-market regulations are instrumented with specific characteristics of the legal system. In particular, we use a country's legal origin to explain governments inclination to intervene in the economy (see La Porta et al., 1999), the underlying hypothesis being that the common law tradition intends to limit the power of the sovereign, whereas the civil legal tradition reflects the intent to build institutions to invigorate the power of the State.²⁸ First stage estimates showing that countries with French, German or Soviet legal origins are characterized by higher administrative burdens to start-ups and entry barriers to services sectors than countries with Scandinavian or British (the excluded category) origins reinforce this idea, supporting our choice of instruments (Panel A, Table B.8). As for the second stage, results presented in Panel B, Table B.8 indicate a negative relation between higher product market regulations and the adoption of digital technologies, confirming previous findings.

84. Finally, given the relatively small size of our sample, it is important to rule out the possibility that coefficient estimates are driven by outliers. We therefore ran rolling regressions dropping one country or sector at a time (see Table B.9 and Table B.10). Results are broadly robust to this further robustness check, with losses in significance occurring in only a handful of cases.

1.4. Complementarity between capabilities and incentives

85. There are good reasons to suspect that market incentives can shape the impact of investment in organisational capital on the adoption of digital technologies. For instance,

²⁸ Following Barseghyan (2008), we also account for geographic latitude.

high-quality management practices might only translate into significant increases of digital adoption rates if market settings underpin the creative destruction process through competition-enhancing policies. In this regard, one might expect the returns to investment in capabilities to be proportionally greater in the absence of entry barriers to new, and in particular young firms, to the extent that young firms possess a comparative advantage in commercialising new technologies (Henderson, 1993; see section 2) thus encouraging managers to experiment with new business strategies and new technologies. In a similar vein, a (policy) complementarity may exist between the quality of management and the ease of adjustment of the workforce. With overly stringent employment protections legislations, managerial decisions concerning a reorganisation of the workforce may be more challenging to implement.

86. To test this conjecture, Table 6 explores the link between the prevalence of high performance work practices (HPWP), proxying for the quality of management, and barriers to competition and reallocation in the form of administrative barriers to start-ups (Panel A), restrictions to digital trade (Panel B), and the stringency employment protections legislations (Panel C). As before, the quantification of an increase in the coverage of workers involved in HPWPs relies on the difference of the effects on digital adoption rates between more and less knowledge intensive sectors. We report results obtained for the first principal component of digital adoption rates as well as for the different technologies.

87. Consistent with our conjecture, the positive effect of managerial quality on adoption is boosted by easier access to markets and reallocation. Lower administrative burdens on startups, more open digital trade and more flexible labour markets increase the positive impact of extending the use of modern managerial practices on the adoption of digital technologies, pointing to a significant complementarity between factors affecting market incentives and firm capabilities.

88. For example, our estimates suggest that the effects of a wider diffusion of HPWPs (i.e. increasing rates observed in each country to the maximum rate in Denmark) on the adoption of cloud computing would be quite different in countries with different market environments (Figure 7). They would be three times larger in countries with low administrative burdens relative to countries with high burdens and twice as large in countries with relatively less stringent EPL regimes. Estimates are less sensitive to barriers to digital trade, even though the effects of improving management on adoption of cloud computing would still be stronger in an open trade environment than with high barriers to trade. Thus, packaging reforms in the capabilities and incentives areas could increase the bang for the buck on adoption rates.

Table 6. The complementarity between incentives and capabilities: the effects of improving managerial practices on adoption depend on the market environment

Dependent variable: percentage of firms >10 employees adopting the digital technology

	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)	1 st principal component
A: Administrative Burdens to Startups					
High-speed internet	0.353*** (0.0648)	0.251*** (0.0742)	0.170** (0.0673)	0.116** (0.0517)	2.784*** (0.660)
HPWP* Knowledge Intensity	8.26e-06 (0.00375)	0.0116*** (0.00256)	0.0121*** (0.00297)	0.0163*** (0.00282)	0.156*** (0.0308)
HPWP* Knowledge Intensity* Administrative Burdens to Startups (PMR)	-0.00204 (0.00221)	-0.00164 (0.00234)	-0.00583*** (0.00211)	-0.00696*** (0.00186)	-0.0684*** (0.0197)
Observations	384	385	364	343	338
R-squared	0.863	0.891	0.909	0.874	0.922
B: Digital Trade Restrictions					
High-speed internet	0.351*** (0.0658)	0.236*** (0.0739)	0.161** (0.0666)	0.0961* (0.0509)	2.647*** (0.650)
HPWP* Knowledge Intensity	-0.00132 (0.00378)	0.0160*** (0.00374)	0.0102*** (0.00306)	0.0170*** (0.00318)	0.142*** (0.0408)
HPWP* Knowledge Intensity *Digital Trade Restrictiveness Index	-0.00521 (0.0172)	-0.0368** (0.0169)	-0.0254** (0.0123)	-0.0453*** (0.0143)	-0.327* (0.174)
Observations	384	385	364	343	338
R-squared	0.863	0.893	0.907	0.869	0.919
C: Employment Protection					
High-speed internet	0.355*** (0.0650)	0.255*** (0.0755)	0.174** (0.0674)	0.119** (0.0522)	2.820*** (0.661)
HPWP* Knowledge Intensity	0.00368 (0.00669)	0.0225*** (0.00536)	0.0200*** (0.00575)	0.0230*** (0.00510)	0.244*** (0.0532)
HPWP* Knowledge Intensity * Employment Protection Legislation	-0.00244 (0.00251)	-0.00525** (0.00238)	-0.00616*** (0.00234)	-0.00611*** (0.00199)	-0.0691*** (0.0206)
Observations	384	385	364	343	338
R-squared	0.863	0.893	0.909	0.870	0.921

Note: This table reports estimates of a model specification in which each digital technology is regressed on the percentage of firms using high-speed broadband connections in a given country-industry cell, the prevalence of high performance work practices interacted with knowledge intensity only, and as a triple interaction term with a policy variable of interest (i.e. product market regulations, digital trade restrictions, and the stringency of employment protection legislation). All regressions include country and industry fixed effects and are based on a country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016. Further triple interactions results are available upon request. Robust standard errors in parenthesis, ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Source: OECD calculations based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017.

Figure 7. A market environment favourable to incentives boosts the impact of enhanced managerial practices on the adoption rate of cloud computing

Increase in CC adoption rates from increasing the diffusion of HPWP to sample maximum level (DNK)

Note: These graphs show the ceteris paribus increase in digital adoption rates from increasing the diffusion of high performance work practices (HPWP) to sample maximum (Denmark), between industries with a high (i.e. 75th percentile) or low (i.e. 25th percentile) knowledge intensity in a policy environment with high (i.e. 75th percentile of the distribution) or low (25th percentile) (A) administrative burdens on start-ups, (B) restrictions on digital trade and (C) employment protections legislations. Calculations are based on results in Table 6. Note that the *lowest* benefit (or increase) is reaped by countries that are close to the sample optimum, as their scope for reform is limited. By construction, the lowest/highest benefit will always be made by the same country within each panel. The average effect is represented by the circle, the 1st and 3rd quartile by the beige bar.

1.5. Policy discussion and further research

1.5.1. Policy implications

89. Policies to revive technological diffusion have come into closer focus, as evidence has emerged that the aggregate productivity slowdown has its roots in rising within-sector productivity dispersion, partly reflecting the flickering ability of laggard firms to catch up to the frontier by adopting latest technologies and business practices (Andrews et al., 2016; Decker et al., 2016; Baily et al., 2016). The results in this paper are consistent with the idea that digital adoption in firms is supported by three overriding factors that can be influenced by policy. First, improving the roll-out of high quality broadband infrastructure is complementary to the adoption of more sophisticated digital applications. As highlighted in Annex C, many governments across the OECD have been proactive in encouraging or promoting access to high-speed broadband networks, notably in the form of national broadband strategies or through co-investment (OECD, 2017c). Our results confirm the importance of roll-out policies for spreading out digital adoption.

90. Even so, significant cross-country differences in digital adoption remain after controlling for the penetration of high-speed broadband, which highlights two additional requirements: the need to lift firms' capabilities and sharpen their incentives to adopt. This in turn requires implementing structural policies that support the technology-skill complementarity and ease access to markets and resource reallocation.

91. On the capabilities side, a key observation is that the complementary intangible investments required for successful adoption of new technologies have become increasingly sophisticated over time. Consistent with this, we find evidence that digital

penetration is more widespread in environments characterised by higher quality management, a wider availability of ICT skills – especially the provision of ICT training to low skilled workers – and a more efficient matching of skills to jobs.

92. While enhancements in managerial practices are chiefly initiated within firms, policies can have an influence by raising incentives to enhance these practices via stronger market competition and discipline as well as via public education, training and the framing (and in some cases the financing) of management schools.²⁹ Also, governments often seek to raise awareness, disseminate good practices, or provide diagnostic tools for companies (especially small and medium-sized enterprises) to identify which measures best suit their needs (OECD, 2016b).³⁰

93. Similarly, a number of policies can help promoting basic digital literacy, which typically rests with education ministries via curriculum-related decisions: for instance, among OECD countries, 80% provide support for vocational training and higher education in ICT.³¹ At later ages broader digital strategies also involve lifelong learning, which our empirical results suggest may facilitate adoption, hinging inter alia on continuous vocational training, adult learning and on-the-job training. Moreover, the provision of e-government services can encourage ICT use by individuals by helping fostering citizens' affinity to digital technologies.

94. Also, both out and on-the-job training are influenced by public policies. For instance, several countries have taken explicit measures to remedy for the gap between training participation rates of the low and high-skilled, for instance by giving priority access to publicly-funded education and training leave to the low-qualified workers (Denmark, Spain) or by funding employers to contribute to the cost of training in various ways (Estonia, France, the Netherlands).³² While the design of such financial incentive schemes is crucial for minimising distortions and maximise their economic and distributional benefits (OECD, 2017d),³³ facilitating and encouraging generic and ICT

²⁹ For a more detailed discussion of the policies affecting the use of effective managerial practices at work, see OECD (2016b).

³⁰ The New Zealand High-Performance Working Initiative, for instance, partly finances business coaching to help streamline work practices and improve performance while also increasing employee engagement and satisfaction. The program is especially designed for small- to medium-sized businesses, which often find it more difficult to adopt such practices, for financial or organisational reasons. Similarly, Germany's "trusted cloud" training program helps SMEs gain an understanding of cloud computing and its possible applications (OECD, 2017b).

³¹ In Sweden, for instance, the Schools Act 2011 posits that "every pupil, on completing primary and lower secondary school, must be able to use modern technology as a tool for knowledge-seeking, communication, creation and learning" (OECD, 2016a; see Table C.1 and Table C.2. for examples in other OECD countries). Later age initiatives include undergraduate degree programmes, courses that may or may not lead to a technical certification, or public-private partnerships to educate ICT specialists (OECD, 2017b).

³² See EC (2015) and OECD (2017d).

³³ For instance, if skills tax expenditures are only available for training connected to a workers' current employment, they may reduce labour market flexibility and exacerbate skills mismatches. Moreover, skills tax expenditures often provide larger benefits to those with larger taxable incomes, and may provide more benefits to those in secure employment than to those in casual

training to low-skilled non-ICT workers can have an impact on the ability to adopt digital technologies.

95. But our analysis highlights that policies aimed at building capabilities are not sufficient if market opportunities and incentives to adopt are weak. In this regard, our results demonstrate the important link between digital diffusion and framework policies that do not unduly inhibit ease of firm entry and exit, competitive pressures and digital trade, reshuffling of the workforce and access to private equity. From this standpoint keeping market reforms at pace with the speed of technological progress is key for adoption as it can have both a direct effect on firm incentives to invest in digital technologies, e.g. to meet competitive pressures, and an indirect effect on complementary intangible investments, such as improvements in managerial capital or the better matching of skills to jobs (Adalet et al., 2015b).³⁴ In sum, as highlighted by our findings on policy complementarity, enhanced capabilities need to be supported by business dynamism and efficient resource reallocation (and vice versa) to bring about significant increases in adoption rates.

96. Finally, quite apart from policies affecting workers' skills, competition or the ease of reallocation within a market, digital adoption rates can also directly be driven by the trust businesses place in digital technologies. Over recent years, however, the level of trust has suffered from a rising amount of (targeted and large-scale) cyber-attacks.³⁵ Since no comparable cross-country data quantifying the effect of cyberattacks is available to date, this aspect exceeds the scope of this report. However, it represents an important issue in the digital agenda of governments, as witnessed for instance by recent policy initiatives at the EU level (Annex C).

1.5.2. Research agenda

97. On the whole, our results suggest that combining reforms aimed at improving the level of managerial expertise and workers' skills with measures aimed at facilitating business dynamism can be an effective way to leverage on the development of digital technologies by increasing their diffusion across firms. In turn, faster and wider diffusion can help close the gap between laggard and frontier firms, which would sustain aggregate productivity growth.

98. However, more research on the barriers to digital adoption is clearly required and a number of avenues for future research thus emerge. First, structural weaknesses that undermine firms' capabilities and incentives to adopt may result in lower digital adoption rates by indirectly suppressing the returns to digital adoption. Accordingly, ongoing work aims to combine the same digital adoption variables exploited in this paper with external industry and firm-level productivity data, in order to explore how the same structural and policy factors shape the productivity returns from investments in digital technologies.

employment. Income-contingent loans may be a way to ensure access to skills investment for credit-constrained workers.

³⁴ This is particularly important given that the benefits of human capital-augmenting policies take a long time to be realised, while improving the allocation of human capital will enhance the 'bang-for-the-buck' (i.e. productivity impact) of such policies.

³⁵ As a result, 57% of large and 38% of small and medium-sized firms in the EU are concerned with the risk of a security-breach when using cloud systems (Eurostat, 2016).

99. Second, future research could explore the extent to which digital technologies enhance the productivity payoffs of other intangible investments. For example, there is evidence that the productivity returns to R&D investment vary significantly across countries (Cincera and Veugelers, 2014). While this is likely to reflect differences in framework policies governing firm entry and exit and resource reallocation more generally, one could imagine that the adoption of digital technologies raises the productivity of R&D spending. Indeed, techno-optimists such as Joel Mokyr (2013) stress the potential for digital technologies to fuel future productivity growth by making advances in basic science more likely, which then feed back into new technologies in a virtuous cycle, via the so-called “artificial revelation”.

100. Finally, as sufficient time-series data on digital adoption becomes available, it would be interesting to explore the extent to which recent structural reforms in product and labour markets have translated into higher digital adoption rates. Time-series data on digital adoption would not only provide stronger identification to test the plausibility of the capabilities and incentives framework but would also provide scope for further testing policy complementarities. For example, recent firm-level evidence suggests that the favourable impact of lower policy-induced entry barriers on technological diffusion – as proxied by the catch-up of laggard firms to the global productivity frontier – is stronger in environments where the insolvency regime does not excessively penalise entrepreneurial failure (Adalet McGowan, Andrews and Millot, 2017b). A logical next step would be to test whether the same complementarity between entry and exit policy is relevant for digital adoption. In the same spirit, time-series data would allow investigating whether delays in digital adoption are related to a mismatch between the pace of market reforms (e.g. in the regulation of new business models, access and transfer of data or services sectors) and the speed of technical progress.

References

- Acemoglu, D., U. Akcigit, N. Bloom and W. Kerr (2013), “Innovation, Reallocation and Growth”, *NBER Working Papers*, No. 18993.
- Adalet McGowan, M., D. Andrews and V. Millot (2017a), “The Walking Dead? Zombie Firms and Productivity Performance in OECD countries”, *OECD Economics Department Working Paper*, No 1372.
- Adalet McGowan, M., D. Andrews and V. Millot (2017b), “Insolvency Regimes, Technology Diffusion and Productivity Growth: Evidence from Firms in OECD Countries”, *OECD Economics Department Working Papers*, No. 1425, Paris. <http://dx.doi.org/10.1787/36600267-en>
- Adalet McGowan, M. and D. Andrews (2015a), “Labour market mismatch and labour productivity: Evidence from PIAAC”, *OECD Economics Department Working Papers*, No 1209.
- Adalet McGowan, M. and D. Andrews (2015b), “Skill Mismatch and Public Policy in OECD Countries”, *OECD Economics Department Working Papers*, No. 1210, Paris. <http://dx.doi.org/10.1787/5js1pzw9lnwk-en>
- Aghion, P., and R. Griffith (2005), *Competition and growth*, MIT Press.
- Andrews, D. C. Criscuolo and P. Gal (2016), “The Best versus the Rest: The Global Productivity Slowdown, Divergence across Firms and the Role of Public Policy”, *OECD Productivity Working Papers*, No. 5.
- Andrews, D., C. Criscuolo and P. Gal (2015), “Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries”, *OECD Productivity Working Papers*, No. 2. <http://dx.doi.org/10.1787/5jrql2q2jj7b-en>
- Andrews, D. and F. Cingano (2014), “Public Policy and Resource Allocation: Evidence from Firms in OECD Countries”, *Economic Policy*, No. 29(78), pp. 253-296.
- Andrews, D. and C. Criscuolo (2013), “Knowledge-Based Capital, Innovation and Resource Allocation”, *OECD Economics Department Working Papers*, No. 1046, Paris. <http://dx.doi.org/10.1787/5k46bj546kzs-en>
- Autor, D., F. Levy and R.J. Murnane (2003a), “The skill content of recent technological change: an empirical exploration”, *Quarterly Journal of Economics*, 118(4): 1279-1333.
- Autor, D.H. (2003b), “Outsourcing at Will: the Contribution of Unjust Dismissal Doctrine to the Growth of Employment Outsourcing”, *Journal of Labor Economics*, 21(1), pp. 1-42.
- Baily, M.N. and N. Montalbano (2016), “Why is US productivity growth so slow? Possible explanations and policy responses”, *Hutchins Center Working Paper*, No. 22, Brookings Institution.
- Barone, G. and F. Cingano (2011), “Service Regulation and Growth: Evidence from OECD Countries”, *The Economic Journal* Volume 121, Issue 555, 2011, June.

- Barseghyan, L (2008), “Entry costs and cross-country differences in productivity and output”, *Journal of Economic Growth* (13), pp. 145–167.
- Bartel, A., C. Ichniowski and K. Shaw (2007), “How does information technology affect productivity? Plant-level comparisons of product innovation, process improvement and worker skills”, *Quarterly Journal of Economics*, 122(4) : 1721-1758.
- Bartelsman, E., G. van Leeuwen and M. Polder (2017), “CDM using a cross-country micro-moments database”, *Economics of Innovation and New Technology*, 26:1-2, 168-182.
- Bartelsman, E., J. Haltiwanger and S. Scarpetta (2009), “Measuring and Analyzing Cross-Country Differences in Firm Dynamics”, in T. Dunne, J.B. Jensen and M.J. Roberts (eds.), *Producer Dynamics*, University of Chicago Press for the NBER, Chicago, Ill.
- Bassanini, A., L. Nunziata and D. Venn (2009), “Job protection legislation and productivity growth in OECD countries”, *Economic Policy*, No. 24(58), pp. 349-402.
- Behaghel, L., E. Caroli and E. Walkowiak (2012), "Information and communication technologies and skill upgrading: the role of internal vs external labour markets," *Oxford Economic Papers*, Oxford University Press, vol. 64(3), pages 490-517, July.
- Beheshti, Hooshang M. & Cyrus M. Beheshti (2010), “Improving productivity and firm performance with enterprise resource planning”, *Enterprise Information Systems*, 4:4, 445-472. DOI: [10.1080/17517575.2010.511276](https://doi.org/10.1080/17517575.2010.511276)
- Bloom, N., L. Garicano, J. V. Reenen and R. Sadun (2014), “The distinct effects of Information Technology and Communication Technology on firm organization”, Lead article, *Management Science* (2014) 60(12) 2259-2885. <http://cep.lse.ac.uk/pubs/download/dp0927.pdf>
- Bloom, N., R. Sadun and J. Van Reenen (2012a), “Americans Do IT Better: US Multinationals and the Productivity Miracle”, *American Economic Review* 102(1): 167–201.
- Bloom, N., C. Genakos, R. Sadun and J. Van Reenen (2012b), “Management Practices Across Firms and Countries”, *NBER Working Paper*, No 17850.
- Bloom, N., M. Draca and J. Van Reenen (2011), “Trade Induced Technical Change: The Impact of Chinese Imports on Innovation, Diffusion and Productivity”, Mimeo. <http://www.stanford.edu/~nbloom/TITC.pdf>
- Bloom, N. and J. v. Reenen (2007), “Measuring and Explaining Management Practices Across Firms and Countries”, *The Quarterly Journal of Economics*, Volume 122, Issue 4, 1 November 2007, Pages 1351–1408, <https://doi.org/10.1162/qjec.2007.122.4.1351>
- Bose, Ranjit (2002) "Customer relationship management: key components for IT success", *Industrial Management & Data Systems*, Vol. 102 Issue: 2, pp.89-97. <https://doi.org/10.1108/02635570210419636>
- Bourlès, R., G. Crette, J. Lopez, J. Mairesse, and G. Nicoletti (2013), “Do Product Market Regulations In Upstream Sectors Curb Productivity Growth? Panel Data Evidence for OECD Countries”, *The Review of Economics and Statistics*, December 2013, Vol. 95, No. 5, pp. 1750–1768
- Brynjolfsson, E., D. Rock and C. Syverson (2017), “Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics”, *NBER Working Paper*, No. 24001.
- Brynjolfsson, E., A. McAfee (2014), *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, W.W. Norton & Co.

- Brynjolfsson, E., A. McAfee, M. Sorell and F. Zhu (2008), "Scale Without Mass: Business Process Replication and Industry Dynamics", *Harvard Business School Technology & Operations Mgt. Unit Research Paper*, No. 07-016.
- Brynjolfsson, E., A. Renshaw and V. Marshall Alstyne (1997), "The Matrix of Change: A Tool for Business Process Reengineering", *Sloan Management Review*, pp. 37-54.
- Cette, G. and J. Lopez (2011), "ICT demand behaviour: an international comparison", *Economics of Innovation and New Technology*, 21:4, 397-410.
- Ciccone, A., and E. Papaioannou (2007), "Red tape and delayed entry", *Journal of the European Economic Association*, 5: 444-458.
- Cincera, M. and R. Veugelers (2014), "Differences in the rates of return to R&D for European and US young leading R&D firms," *Research Policy, Elsevier*, vol. 43(8), pages 1413-1421.
- Comin, D. and M. Mestieri (2013), "If Technology Has Arrived Everywhere, Why Has Income Diverged?", *NBER Working Paper*, No. 19010.
- Criscuolo, C., J. Timmis and N. Johnstone (2016), "The Relationship between GVCs and Productivity", Background Paper to the 2016 Conference of the Global Forum on Productivity. Available from: http://www.oecd.org/global-forumproductivity/events/Relationship_between_GVCs_and_productivity_6_09_2016.pdf
- Criscuolo, C., P. Gal and C. Menon (2014), "The Dynamics of Employment Growth: New Evidence from 18 Countries", *OECD Science, Technology and Industry Policy Papers*, No. 14, Paris. <http://dx.doi.org/10.1787/5jz417hj6hg6-en>
- Decker, R., J. Haltiwanger, R. S. Jarmin and J. Miranda (2017), "Declining Dynamism, Allocative Efficiency, and the Productivity Slowdown", *FEDS Working Paper*, No. 2017-019.
- Decker, R., J. Haltiwanger, R.S. Jarmin, and J. Miranda (2016), "Declining Business Dynamism: Implications for Productivity?", *Brookings Institution, Hutchins Center Working Paper*.
- DeStefano, T., K. De Backer and L. Moussié (2017), "Determinants of digital technology use by companies", *OECD Science, Technology and Industry Policy Papers*, No. 40, OECD Publishing, Paris. <https://doi.org/10.1787/a9b53784-en>
- Dhyne, E., J. Konings, J. van den Bosch and S. Vanormelingen (2017), "IT and productivity: a firm level analysis", paper presented at the OECD-IZA Workshop on Labour Productivity and IT, Paris (October).
- Draca, M., R. Sadun, & J. Van Reenen (2007), "Productivity and ICTs: A review of the evidence", *The Oxford Handbook of Information and Communication Technologies*, 100-147, Oxford University Press.
- ECIPE (2018), DTE Report <http://ecipe.org/dte/database/>
- Égert, B., T. Kozluk and D. Sutherland (2009), "Infrastructure and Growth: Empirical Evidence", *OECD Economics Department Working Papers*, No. 685, Paris. <http://dx.doi.org/10.1787/225682848268>
- European Commission (2018), "Broadband Cost Reduction Directive: Commission refers Bulgaria and the Netherlands to the Court and closes two cases", Press Release, available at http://europa.eu/rapid/press-release_IP-18-352_en.htm
- European Commission (2017a), "The BCO Network Support Facility", available at https://ec.europa.eu/digital-single-market/sites/digital-agenda/files/bco_network_support_facility_-_activity_report_2017.pdf

- European Commission (2017b), EURES, The European Job Mobility Portal, webpage, <https://ec.europa.eu/eures/main.jsp?catId=8440&acro=living&lang=en&parentId=7783&countryId=IT&living=> (Accessed on 22 July 2018).
- European Commission/EACEA/Eurydice (2015), “Adult Education and Training in Europe: Widening Access to Learning Opportunities”, Eurydice Report. Luxembourg: Publications Office of the European Union.
- Eurostat (2016), “Cloud Computing – statistics on the use by enterprises”, Statistics Explained (http://ec.europa.eu/eurostat/statistics-explained/index.php/Cloud_computing_-_statistics_on_the_use_by_enterprises)
- Fabling, R., and A. Grimes (2016), “Picking up speed: Does ultrafast broadband increase productivity?”, Motu Working Paper 16-22, Motu Economic and Public Policy Research (November).
- Falck, O. and S. Wiederhold (2015), *ICT skills are highly valued in European labor markets*, September 2015.
- Financial Times (19.11.2017), *Companies face high costs to meet new EU data rules*.
- Gal, P., G. Nicoletti, T. Renault, S. Sorbe and C. Timiliotis (2018), “Digitalisation and productivity: in search of the Holy Grail”, *forthcoming*.
- Gartner (2017), “Market Share Analysis: ERP Software Worldwide, 2016”, Gartner.
- Glaeser, L. E. and M. G. Resseger (2010), “The Complementarity between Cities and Skills”, *Journal of Regional Science*, 50(1) (2010): 221 - 2 44 .
- Griffith, R. and G. Macartney (2010), "Employment Protection Legislation, Multinational Firms and Innovation", *CEPR Discussion Papers*, No. 7628.
- Griffith, T., Zammuto, R., & Aiman-Smith, L. (1999), Why new technologies fail, *Industrial Management* (DesPlaines), 29–34.
- Guellec, D. and C. Paunov (2017), “Digital Innovation and the Distribution of Income”, *NBER Working Paper*, No. 23987.
- Guerrieri, P., M. Luciani and V. Meliciani (2011), “The determinants of investment in information and communication technologies”, *Economics of Innovation and New Technology*, 20:4, 387-403.
- Hall, B.H. and J. Lerner (2009), "The Financing of R&D and Innovation", *NBER Working Paper* No. 15325.
- Hathaway, I. and R.E. Litan (2014), “Declining business dynamism in the United States: a look at States and Metros”, *Economic Studies*, Brookings Institution, Washington D.C.
- Henderson, R. (1993). "Underinvestment and Incompetence as Responses to Radical Innovation: Evidence from the Photolithographic Alignment Equipment Industry", *RAND Journal of Economics*. 24(2) pp. 248–270.
- Hong, K., & Kim, Y. (2002), “The critical success factors for ERP implementation: An organizational fit perspective”, *Information & Management*, 40(1), 25–40.
- Hunton, James E., Barbara Lippincott, Jacqueline L. Reck (2003): “Enterprise resource planning systems: comparing firm performance of adopters and nonadopters”, *International Journal of Accounting Information Systems*, Vol. 4, p. 165-184.
- Klapper, L., L. Laeven and R. Rajan (2006), "Entry Regulation as a Barrier to Entrepreneurship", *Journal of Financial Economics*, 82, pp. 591-629.

- Koske, I., I. Wanner, R. Bitetti and O. Barbiero (2015), “The 2013 update of the OECD product market regulation indicators: policy insights for OECD and non-OECD countries”, *OECD Economics Department Working Papers*, No. 1200.
- Kumar, V., Maheshwari, B., & Kumar, U. (2003), An investigation of critical management issues in ERP implementation: Empirical evidence from Canadian organizations, *Technovation*, 23(10), 793–808.
- La Porta, R., Lopez de Silanes, F., Shleifer, A., & Vishny, R. W. (1999), “The quality of government”, *Journal of Law, Economics, and Organization*, (15), pp. 222–279.
- Machin, S. and J. van Reenen (1998), “Technology and changes in skill structure: evidence from seven OECD countries”, *Quarterly Journal of Economics*, 113(4): 1215–1244
- Marcolin, L., S. Miroudot and M. Squicciarini (2016), “The Routine Content Of Occupations: New Cross-Country Measures Based On PIAAC”, *OECD Trade Policy Papers*, No. 188, OECD Publishing, Paris.
- McKinsey Global Institute (2018), *Solving the Productivity Puzzle: The Role of Demand and the Promise of Digitization*, McKinsey and Company.
- Mokyr, J., (2013), “Is technological progress a thing of the past?”, *VoxEU*, <https://voxeu.org/article/technological-progress-thing-past>
- OECD (2018a), Indicators of Product Market Regulation website: <http://www.oecd.org/eco/growth/indicatorsofproductmarketregulationhomepage.htm>
- OECD (2018b), Indicators of Employment Protection, <http://www.oecd.org/els/emp/oecdindicatorsofemploymentprotection.htm>
- OECD (2017a), *Going Digital: Making the Transformation Work for Growth and Well-Being*, Meeting of the OECD Council at Ministerial Level, Paris, 7-8 June 2017.
- OECD (2017b), *OECD Digital Economy Outlook 2017*, OECD Publishing, Paris. <http://dx.doi.org/10.1787/9789264276284-en>
- OECD (2017c), *OECD Territorial Reviews: Northern Sparsely Populated Areas*, OECD Publishing, Paris. <http://dx.doi.org/10.1787/9789264268234-en>
- OECD (2017d), *Tax and Skills*, OECD Publishing, Paris. <http://dx.doi.org/10.1787/9789264269385-en>
- OECD (2017e), *OECD Economic Surveys: Italy 2017*, OECD Publishing, Paris. http://dx.doi.org/10.1787/eco_surveys-ita-2017-en
- OECD (2017f), *OECD Science, Technology and Industry Scoreboard 2017: The digital transformation*, OECD Publishing, Paris <http://dx.doi.org/10.1787/9789264268821-en>
- OECD (2016a), “Skills for a Digital World: 2016 Ministerial Meeting on the Digital Economy Background Report”, *OECD Digital Economy Papers*, No. 250, OECD Publishing, Paris. <http://dx.doi.org/10.1787/5jlwz83z3wnw-en>
- OECD (2016b), *OECD Employment Outlook 2016*, OECD Publishing, http://dx.doi.org/10.1787/empl_outlook-2016-en
- OECD (2016c), *Education at a Glance 2017: OECD Indicators*, OECD Publishing, Paris. <http://dx.doi.org/10.1787/eag-2017-en>
- OECD (2016d), Skills Matter: Further Results from the Survey of Adult Skills, *OECD Skills Studies*, OECD Publishing, Paris. <http://dx.doi.org/10.1787/9789264258051-en>

- OECD (2015), *The Future of Productivity*, OECD Publishing, <http://dx.doi.org/10.1787/9789264248533-en>
- OECD (2013a), *Supporting Investment in Knowledge Capital, Growth and Innovation*, OECD Publishing, Paris, <http://dx.doi.org/10.1787/9789264193307-en>.
- OECD (2013b), *OECD Skills Outlook 2013: First Results from the Survey of Adult Skills*, OECD Publishing, Paris, <http://dx.doi.org/10.1787/9789264204256-en>.
- OECD (2012), "ICT skills and employment: New competences and jobs for a greener and smarter economy", *OECD Digital Economy Papers*, No. 198, OECD Publishing, Paris. <http://dx.doi.org/10.1787/5k994f3prlr5-en>.
- Oliveira, T. and Martins (2011), "Literature review of IT adoption models at firm level", *The Electronic Journal Information Systems Evaluation*, 14(1) : 110-121.
- Ollivaud, P., Y. Guillemette and D. Turner (2016), "The Links between Weak Investment and the Slowdown in OECD Productivity and Potential Output Growth", *OECD Economics Department Working Papers*, No. 1304.
- Panorama Consulting Solution (2015); "Key findings - The 2015 ERP Report", available at <https://www.panorama-consulting.com/key-findings-from-the-2015-erp-report/>
- Parente, S. L. and E. C. Prescott. (1999). "Monopoly Rights: A Barrier to Riches." *American Economic Review*, 89 (5): 1216-1233.
- Pellegrino, B. and L. Zingales (2017): "Diagnosing the Italian Disease", *NBER Working Paper*, No. 23964.
- Perla, J., C. Tonetti and M. E. Waugh (2015), "Equilibrium Technology Diffusion, Trade, and Growth," *NBER Working Papers*, No. 20881, National Bureau of Economic Research, Inc.
- Rajan, R. and L. Zingales (1998), "Financial dependence and growth", *American Economic Review*, Vol. 88, pp.559-586.
- Reenen, J. V., S. Scott and M. Zachariadis (2017), "The impact of the diffusion of a financial innovation on company performance: an analysis of SWIFT", *CEP Discussion Papers* No. 992.
- Rogers, Everett (1997), *Diffusion of innovations*, The Free Press, New York.
- Saia, A., D. Andrews and S. Albrizio (2015), "Productivity Spillovers from the Global Frontier and Public Policy: Industry-Level Evidence", *OECD Economic Department Working Paper*, No. 1238, OECD Publishing.
- Schwab, Klaus (2017), "The Global Competitiveness Report 2016–2017", *World Economic Forum*.
- Stevenson, Betsey (2008): "[The Internet and Job Search](#)," *NBER Working Papers* No 13886, National Bureau of Economic Research, Inc.
- Wasmer, E. (2006), "Interpreting Europe-US Labor Market Differences: the Specificity of Human Capital Investments", *American Economic Review*, 96(3), pp. 811-31.
- Zellner, A. (1962), "An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias", *Journal of the American Statistical Association* 57(298), 348-368.
- Zhang, Z., Lee, M., Huang, P., Zhang, L., & Huang, X. (2005), A framework of ERP systems implementation success in China: An empirical study, *International Journal of Production Economics*, 98(1), 56–80.

Annex A. Description of the data and variables used

Table A.1. Description of variables and sources

	Description	Coverage	Source	Link (if available)
Digital Technologies				
Broadband	Enterprises with broadband access (fixed or mobile) (E_BROAD2)	2010-15	Eurostat - Digital economy and society statistics - households and individuals	http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensive-database
High-speed Broadband	Maximum contracted download speed of the fastest internet connection is at least 30 Mb/s (e_ispdf_ge30)	2014-2016	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	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	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	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	Eurostat - Digital economy and society statistics - households and individuals	http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensive-database
Incentives				
EPL	Strictness of employment protection (Collective and individual dismissal, regular contracts, Version 3)	2010-13	OECD Indicators of Employment Protection	http://dotstat.oecd.org/Index.aspx?QueryId=79221
Insolvency regimes	Aggregate insolvency indicator (Insol-13)	2010	OECD Insolvency Regime Indicators	http://www.oecd.org/eco/growth/exit-policies-and-productivity-growth.htm
Venture Capital	Total Venture capital expressed as a percentage of GDP	2010-15	Eurostat	https://data.europa.eu/euodp/dataset/V1eagdl3oK5ZPzkT0PCZw
Barrier to services sectors	PMR subcomponent of Administrative barriers to start-ups	2013	OECD Product Market Regulation Index	For more information see Koske et al. (2015)
Administrative barriers to start-ups	PMR subcomponent of barriers to entrepreneurship	2013	OECD Product Market Regulation Index	For more information see Koske et al. (2015)
Digital trade restrictions	Aggregate Digital Trade Restrictiveness Index	2017	European Centre for International Political Economy	http://ecipe.org/dte/database/
Tax incentives	Indirect government support through R&D tax incentives	2013	OECD Science, Technology and Industry Scoreboard 2015 - © OECD 2015	http://dx.doi.org/10.1787/sti_scoreboard-2015-en
Legal origin	Categorical indicators of whether a country's legal system is based on British common law, on French, German, or Scandinavian civil law, or inherited from Soviet laws	N.A.	La Porta et al., 1999	https://scholar.harvard.edu/shleifer/publications/legal-origins
Capabilities				
Quality of Management school	Quality of management schools, 1-7(best) (Weighted average 14-15)	Average 2014-15	The Global Competitiveness Report 2015–2016 (2016), World Economic Forum	http://reports.weforum.org/global-information-technology-report-2016/technical-notes-and-sources/
High performance work practices	Share of jobs with high HPWPa (all factors) in %	Average 2012;2015	OECD Programme for the International Assessment of Adult Competencies (PIAAC)	https://doi.org/10.1787/empl_outlook-2016-graph34-en http://dx.doi.org/10.1787/888933273688

Lifelong learning	Share of adults participation in lifelong learning	Average 2012	OECD Programme for the International Assessment of Adult Competencies (PIAAC)	For more information see Adalet McGowan and Andrews (2015).
Percentage of low skilled in training	Participation in formal and/or non-formal education level 0-2	Average 2012;2015	OECD Programme for the International Assessment of Adult Competencies (PIAAC)	http://dx.doi.org/10.1787/888933398714
Percentage of high skilled in training	Participation in formal and/or non-formal education level 3-5	Average 2012;2015	OECD Programme for the International Assessment of Adult Competencies (PIAAC)	http://dx.doi.org/10.1787/888933398714 .
Percentage of adults with no ICT skills	Percentage share of adults (15-65) with no ICT experience	2013	OECD Programme for the International Assessment of Adult Competencies (PIAAC)	http://dx.doi.org/10.1787/888933454580
ICT training	ICT training provided to employees (other than ICT specialists) (ITUST2)	2012; 2014-16	Eurostat - Digital economy and society statistics - households and individuals	http://ec.europa.eu/eurostat/web/digital-economy-and-society/data/comprehensive-database
E-Government	Individuals using the Internet to interact with public authorities, as a percentage of the population in each age group	2016	OECD Science, Technology and Industry Scoreboard 2017	http://dx.doi.org/10.1787/9789264268821-en
Skill mismatch	Share of over- and under-skilled workers.	2011-12	Adalet McGowan, M. and D. Andrews (2015)	https://www.oecd.org/eco/growth/Skill-mismatch-and-public-policy-in-OECD-countries.pdf
Urban concentration	Ratio between total population and total land area	2010-14	OECD STAN	http://dotstat.oecd.org/Index.aspx?QueryId=85051
Average firm size		2010-15	Annual enterprise statistics by size class for special aggregates of activities (NACE Rev. 2)	Link
Exposure variable				
Firm Turnover	The sum of industry-level entry and exit rates for the United States over the period 1987-1997. The entry rate is defined as the ratio of new firms to the total number of active firms in a given year. The exit rate is defined as the ratio of firms exiting the market in a given year to the total number of active firms in the previous year.	1988-97	Bartelsmann, Haltiwanger and Scarpetta (2009)	N.A.
External Financial Dependency	Industry external finance dependency (USA)	1980's	Rajan, R. and L. Zingales (1998)	N.A.
Knowledge Intensity	Share of labour compensation of personnel with tertiary education (USA)	1995-2000	OECD (2013)a	http://dx.doi.org/10.1787/9789264193307-en
Job Turnover	Industry turnover rate (job turnover)	2001-2003	Bassanini, Nunziata and Venn (2009)	https://sites.google.com/site/bassanini/home/files/Solowlucasdata.zip?attredirects=0&d=1
Share of computer services inputs	Share computer service (ISIC Rev4 sector C72: Computer and related activities) purchases, percentage of total purchases by sector	2011	OECD Input-Output tables	OECD Stat (http://dotstat.oecd.org/Index.aspx?QueryId=83880)
Routine tasks	Share of high routine employment	2010-15	Marcolin et al. (2016), based on the OECD Programme for the International Assessment of Adult Competencies (PIAAC) and European Labour Force Survey (1995-2015).	N.A.

Table A.2. Country coverage

Austria	Germany	Ireland	Netherlands	Slovenia
Belgium	Finland	Italy	Norway	Spain
Czech Republic	France	Iceland	Portugal	Sweden
Denmark	Greece	Lithuania	Poland	Turkey
Estonia	Hungary	Latvia	Slovakia	United Kingdom

Table A.3. Summary statistics (average values)

	Obs	Mean	Std. Dev.	Min	Max
Digital Technologies					
Broadband	584	0.946802	0.051133	0.695283	1
High-speed Broadband	482	0.354903	0.181625	0.083697	0.957265
Cloud Computing	471	0.242504	0.158422	0.027143	0.886937
Cloud Computing (high)	460	0.138761	0.113644	0	0.652319
ERP	561	0.317957	0.172684	0	0.892771
CRM	552	0.341974	0.188405	0	1
SCM	512	0.213778	0.109067	0	0.634383
Big data	376	0.121444	0.074436	0.00941	0.442308
Social Media	523	0.420708	0.184788	0	0.918744
Incentives					
EPL	625	2.529961	0.343966	1.721089	3.204082
Insolvency regimes	550	0.486888	0.118902	0.130769	0.7
Venture Capital	401	0.0311	0.020665	0.002556	0.075
Barriers in services sectors	630	3.480308	0.67593	1.365741	4.615741
Administrative barriers to start-ups	630	2.00624	0.479206	1.121914	3.080247
Digital trade restrictions	626	.2152077	.0634429	.11	.38
Tax incentives	551	0.7306	0.070	0	0.26
Capabilities					
Quality of Management school	626	4.883414	0.716024	3.687408	6.099314
High performance work practices	500	26.05715	9.044642	10.17509	41.6223
Lifelong learning	425	50.72941	12.42818	24.3	66.8
Percentage of low skilled in training	450	35.06356	11.61629	15.84475	51.69505
Percentage of high skilled in training	450	63.76499	13.37589	31.32726	80.72747
Percentage of adults with no ICT skills	425	20.15593	11.16819	7.243739	43.25481
ICT training	520	0.243814	0.158819	0.02228	0.884082
E-Government	551	55.817.1	17.1	24.1	85
Skill mismatch	525	25.57619	5.604652	18.1	38.3
Exposure Variables					
Firm Turnover (turn)	600	20.05418	3.286501	11.66	26.418
External Financial Dependency (EDF)	550	1.323394	1.32947	-0.19	3.35
Knowledge Intensity (KI)	625	0.422533	0.163885	0.17	0.62
Job turnover	525	44.36817	12.2063	26.69683	88.41486
Share of computer services inputs	625	3.05	2.57	0.57	8.31
Routine tasks	500	0.155	0.11	0.008	0.4

Note: This table presents summary statistics for the entire dataset, i.e. over 25 countries and 25 non-farming business sectors.

Table A.4. Summary statistics for digital technologies, by year

	Year	Mean	Std. Deviation	Observations	Minimum	Maximum
High-speed internet	2010	.	.	0	.	.
ERP	2010	0.2427242	0.1666373	522	0	0.869444
CRM	2010	0.3170005	0.2000798	497	0	1
CC	2010	.	.	0	.	.
CC (complex)	2010	.	.	0	.	.
High-speed internet	2012	.	.	0	.	.
ERP	2012	0.26323	0.1595901	452	0	0.81877
CRM	2012	.	.	0	.	.
CC	2012	.	.	0	.	.
CC (complex)	2012	.	.	0	.	.
High-speed internet	2013	.	.	0	.	.
ERP	2013	0.3112267	0.1708284	445	0	0.8075
CRM	2013	.	.	0	.	.
CC	2013	.	.	0	.	.
CC (complex)	2013	.	.	0	.	.
High-speed internet	2014	0.3171845	0.1741267	424	0	0.844943
ERP	2014	0.3518383	0.1875449	443	0.009897	1
CRM	2014	0.3141914	0.1767704	434	0.016865	1
CC	2014	0.2277052	0.1588404	437	0.009083	0.886937
CC (complex)	2014	0.1284627	0.1116045	417	0	0.666894
High-speed internet	2015	0.3533255	0.189691	461	0.047916	0.92
ERP	2015	0.3813249	0.1865499	436	0.032499	0.946042
CRM	2015	0.3373869	0.1717926	462	0.028658	0.839789
CC	2015	0.2354332	0.1725071	246	0.003937	0.824419
CC (complex)	2015	0.1296086	0.1155694	250	0	0.64928
High-speed internet	2016	0.394993	0.1937918	451	0.061394	0.957265
ERP	2016	.	.	0	.	.
CRM	2016	.	.	0	.	.
CC	2016	0.2569307	0.1689845	398	0.020321	0.854624
CC (complex)	2016	0.1475285	0.1247118	433	0	0.675505

Note: This table presents summary statistics for the entire dataset, i.e. over 25 countries and 25 non-farming business sectors.

Table A.5. Average adoption rates by industry (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
64	Other monetary intermediation, other credit granting	0.295902	0.607317		
65	Insurance, reinsurance	0.409749	0.613659		
66	Security and commodity contracts brokerage, other activities auxiliary to financial services, except insurance and pension funding	0.199761	0.458276		
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

Note: This table reports average adoption rates across industries for a set of 25 countries (see Table A.2 for coverage) 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).

Figure A.1. Enterprises using cloud computing services, by firm size, 2016

As a percentage of enterprises in each employment size class.

Note: Cloud computing refers to ICT services used over the Internet as a set of computing resources to access software, computing power, storage capacity and so on. Data refer to manufacturing and non-financial market services enterprises with ten or more persons employed, unless otherwise stated. OECD data are based on a simple average of the available countries. For country exceptions, see note 5 at the end of the chapter.

Source: OECD (2017b) based on ICT Access and Usage by Businesses (database), <http://oe.cd/bus> (accessed June 2017).

Figure A.2. Use of enterprise resource planning software, by firm size, 2015

As a percentage of enterprises in each employment size class

Note: Unless otherwise stated, sector coverage consists of all activities in manufacturing and non-financial market services. Only enterprises with ten or more persons employed are considered.

Source: OECD (2017b) based on ICT Access and Usage by Businesses (database), <http://oe.cd/bus> (accessed June 2017).

Table A.6. High-speed broadband connections are critical to the adoption of all digital

Dependent variable: percentage of firms >10 employees adopting the digital technology

Technology	ERP	CRM	CC	CC High
High Speed Internet (>30 Mbit/s)	0.214*** (0.0477)	0.248*** (0.0425)	0.178*** (0.0378)	0.110*** (0.0343)
Constant	0.372*** (0.0303)	0.385*** (0.0264)	0.112*** (0.0204)	0.0504** (0.0196)
Observations	477	477	456	435
R-squared	0.850	0.876	0.906	0.845

Note: The results show estimates for the percentage of firms adopting ERP, CRM or CC technologies regressed on the percentage of firms using high-speed internet, country and industry fixed effects; ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Table A.7. The enabling role of Cloud Computing for ERP and CRM adoption

	ERP	CRM
High-speed internet	0.208*** -0.0646	0.151*** -0.0529
Cloud Computing	0.173** -0.081	0.472*** -0.0607
Constant	0.345*** -0.0296	0.336*** -0.0207
Observations	452	453
R-squared	0.855	0.898

Note: The results show the role of Cloud Computing for the adoption of Enterprise Resource Planning and Customer Relationship Management software. Regressions also account for the percentage of firms using high-speed internet, country and industry fixed effects; ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Table A.8. Correlations across digital technologies

	Broadband	High-speed broadband	Cloud Computing	Cloud Computing (complex)	ERP	CRM
Broadband	1					
High-speed broadband	0.098**	1				
Cloud Computing	-0.0079	0.2252***	1			
Cloud Computing (complex)	-0.1074**	0.1598***	0.7279***	1		
Enterprise Resource Planning	0.1599***	0.206***	0.1257***	0.0656	1	
Customer Relationship Management	0.084**	0.2518***	0.3562***	0.3097***	0.4689***	1

Note: ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Figure A.3. The quality of management**Panel A. High-Performance Work Practices (HPWP) across countries**

Share of jobs with high and mean HPWP score (average value, across jobs, of the HPWP index), 2012, 2015

Note: This figure shows the variation in high performance work practices across OECD countries. The index is constructed using data from the OECD Programme for the Assessment of Adult Competencies (PIAAC) and is based on a set of 9 indicators that are broadly categorized as ‘work organisation’ and ‘management practices’. ‘High’ HPWP refers to the top 25th percentile of the pooled distribution. Data for Belgium corresponds to Flanders.

Source: OECD (2016b)

Panel B. The quality of management schools

Note: Based on the question: “In your country, how would you assess the quality of business schools? [1 = extremely poor—among the worst in the world; 7 = excellent—among the best in the world]”; 2013–14 weighted average.

Source: World Economic Forum, Executive Opinion Survey (Schwab, 2017).

Figure A.4. Individuals using the Internet to interact with public authorities (E-Government) by age, 2016

As a percentage of the population in each age group

Note: For Australia, data refer to the fiscal years 2010/11 ending on 30 June and 2012/13. Data refer to "Individuals who have used the Internet for downloading official forms from government organisations' web sites, in the last 12 months" and "Individuals who have used the Internet for completing/lodging filled in forms from government organisations' web sites, in the last 12 months".

For Brazil and Chile, data refer to 2015. For Canada, data refer to 2012. For Iceland and Switzerland, data refer to 2014. For Israel, data refer to 2015 and to individuals aged 20 and more instead of 16-74, and 20-24 instead of 16-24. Data relate to the Internet use for obtaining services online from government offices, including downloading or filling in official forms in the last 3 months. For New Zealand, data refer to 2012 and to individuals using the Internet for obtaining information from public authorities in the last 12 months. For Japan, data refer to 2015 and to individuals aged 15-69 instead of 16-74 using the Internet for sending filled forms via public authority websites in the last 12 months.

For Mexico, using e-government services includes the following categories: "communicating with the government", "consulting government information", "downloading government forms", "filling out or submitting government forms", "carrying out government procedures" and "participating in government consultations". For "sending forms", data correspond to the use of the Internet in the last 3 months. For Switzerland, e-government refers only to public administrations at local, regional or country level referred as "public administration or authorities". Data exclude health or education institutions.

Source: OECD (2017f)

Figure A.5. Education and training**Panel A. Many adults still lack basic computer skills**

Percentage share of adults (15-65) with insufficient or no ICT experience

Source: OECD (2013b)

Panel B. Participation of adults in education and training by skill level

Share of adults (25-65 year-olds) participating in formal and/or non-formal education and training by literacy level, 2012 or 2015

Note: Participation in formal and/or non-formal education refers to participation in the 12 months prior to the survey. Columns showing data broken down by gender are available for consultation on line (see Statlink below). For Chile, Greece, Israel, Lithuania, New Zealand, Singapore, Slovenia and Turkey, the year of reference is 2015. For all other countries it is 2012.

Source: OECD (2016c), Education at a Glance 2016: OECD indicators, OECD Publishing, Paris, <http://dx.doi.org/10.1787/888933398714>.

Figure A.6. Entry and exit**Panel A. Indicators of Product Market Regulations, 2013**

Higher values indicate higher barriers to entry

Note: The above graph shows two sub-indicators of the economy-wide OECD Product Market Regulations Indicator for 2013.

Source: OECD Product Market Regulations Indicator, http://www.oecd.org/eco/reform/Indicators_PMR.xlsx

Panel B. OECD indicator of insolvency regimes, 2016

Composite indicator based on 13 components, increasing in barriers to exit or restructuring

Note: Calculations based on the OECD questionnaire on insolvency regimes.

Source: Adalet McGowan et al. (2017b)

Figure A.7. Labour market settings

Source: OECD Indicators of Employment Protection Legislation, see <http://www.oecd.org/els/emp/oecdindicatorsofemploymentprotection.htm>

Figure A.8. Access to capital, average 2010-2015

Note: Venture capital investment (VCI) is a subset of a private equity raised for investment in companies not quoted on stock market and developing new products and technologies. It is used to fund an early-stage (seed and start-up) or expansion of venture (later stage venture).

Source: Eurostat, Venture Capital Investment, see <http://ec.europa.eu/eurostat/web/products-datasets/-/tin00141>

Figure A.9. R&D fiscal incentives, 2013

Note: For Belgium, Brazil, Ireland, Israel, South Africa, Spain, Switzerland and the United States, figures refer to 2012. For Australia, Iceland, Mexico and the Russian Federation, figures refer to 2011.

Source: OECD, R&D Tax Incentive Indicators, www.oecd.org/sti/rd-tax-stats.htm and Main Science and Technology Indicators, www.oecd.org/sti/msti.htm.

Figure A.10. Digital trade openness

Composite indicator based on four subcomponents; increasing in barriers to digital trade

Note: The European Centre for Internal Political Economy (ECIPE) Digital Trade Restrictiveness Index (DTRI) index captures trade restrictions in four large areas: (1) fiscal restrictions, (2) establishment restrictions, (3) restrictions on data and (4) trading restrictions. Cluster 3, covering the restrictiveness of data policies, intermediaries' liability and content access restrictions is separately presented in the graph above.

Source: ECIPE (2018)

Annex B. Robustness and additional results

Table B.1. Principal Component Analysis

	Dependent variable: PC1 (Broadband, Social Media, High Speed Internet, ERP, CRM, CC, CC complex, Supply Chain Management, Big Data)				Dependent variable: PC2 (ERP, CRM, CC, CC complex)			
	Policy variable	High-speed broadband	Obs	R2	Policy variable	High-speed broadband	Obs	R2
I. Organisational capital								
Quality of Management School X knowledge intensity	1.334***	4.057***	337	0.933	1.650***	2.490***	429	0.918
High performance work practices X knowledge intensity	0.0655**	4.220***	281	0.934	0.0807***	2.797***	338	0.917
II. Talent Pool								
Percentage of adults with no ICT skills X knowledge intensity	-0.0741***	3.817***	243	0.943	-0.101***	2.807***	297	0.926
Low skilled in training X knowledge intensity	0.0484**	4.371***	253	0.937	0.0897***	2.986***	308	0.929
High skilled in training X knowledge intensity	0.0377*	4.372***	253	0.937	0.0654***	3.082***	308	0.925
Lifelong learning X knowledge intensity	0.0533***	3.680***	243	0.942	0.0897***	2.570***	297	0.926
E-Government x knowledge intensity	0.0500***	3.943***	271	0.925	0.0550***	2.384***	363	0.911
Skill mismatch X knowledge intensity	-0.109***	4.439***	303	0.933	-0.112***	2.805***	360	0.914
Incentives								
Employment protection legislation X turnover	-0.0919***	4.283***	337	0.930	-0.0648***	2.669***	429	0.908
PMR Administrative burdens on start-ups x turnover	-0.0839***	4.335***	337	0.931	-0.0473***	2.685***	429	0.908
PMR Barriers in services sectors X turnover	-0.0439***	4.329***	337	0.930	-0.0320***	2.718***	429	0.908
Insolvency regime rigidity X financial dependency	-0.418*	4.437***	293	0.926	-0.392**	2.845***	371	0.913
Venture capital X financial dependency	4.413***	2.669***	211	0.954	5.298***	2.538***	265	0.930
Tax incentive support for BERD X Knowledge Intensity	5.038	4.045***	293	0.929	3.632	2.782***	364	0.904
Digital Trade Restrictiveness Index X Share of Computer services as input into sector x	-0.367	3.965***	337	0.928	-0.607**	2.447***	429	0.908

Note: This table reports baseline estimates of the baseline equation where digital adoption is regressed on the percentage of firms using high-speed broadband connections in a given country-industry cell, one policy variable of interest interacted with the relevant exposure variable (knowledge intensity, industry firm turnover, sector dependency on external finance or the industry share of computer services as inputs) and country and industry fixed effects. Digital adoption is given by the first principal component (i.e. the one associated with the largest eigenvalue) from a principal component analysis of seven (Panel A) and four (Panel B) variables of digital adoption. Regressions are based on a country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016.

***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Source: OECD calculations based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017.

Table B.2. Baselines estimates controlling for GDP**Panel A. Capabilities, GDP and digital adoption**

Dependent variable: percentage of firms with >10 employees adopting digital technologies (1st principal component of ERP, CRM, CC and CC complex)

Policy variable	Quality of Management schools	High performance work practices	Percentage of adults with no ICT skills	Low skilled in training	High skilled in training	Lifelong learning	E-Government	Skill mismatch
Policy variable x knowledge intensity	2.031***	0.0885***	-0.100***	0.0987***	0.0692***	0.103***	0.0602***	-0.108***
GDP x knowledge intensity	-5.37e-07**	4.05e-07*	1.24e-07	4.35e-07*	2.46e-07	6.42e-07***	6.24e-07***	2.75e-07
High-speed broadband access (>30 Mbit/s)	2.358***	2.882***	2.849***	3.004***	3.096***	2.691***	2.528***	2.884***
Observations	429	338	297	308	308	297	363	360

Panel B. Incentives, GDP and digital adoption

Dependent variable: percentage of firms with >10 employees adopting digital technologies (1st principal component of ERP, CRM, CC and CC complex)

Policy variable	PMR Administrative burdens on start-ups x Turnover	PMR Barriers in services sectors x Turnover	Digital Trade Restrictiveness Index x Share of computer services as input into sector x	Employment Protection Legislation x Turnover	Venture Capital x Financial Dependency	Tax incentive support for BERD x Knowledge Intensity	Insolvency Regimes Rigidity x Financial Dependency
Policy variable	-0.0510***	-0.0311***	-1.001***	-0.0649***	5.232***	-2.492	-0.341
GDP x exposure variable	-1.25e-08*	-4.36e-09	4.58e-08***	-8.57e-09	-8.39e-09	2.74e-07	1.06e-08
High-speed broadband access (>30 Mbit/s)	2.723***	2.723***	2.547***	2.688***	2.518***	2.814***	2.859***
Observations	429	429	429	429	265	386	371

Note: This tables reports estimates of the baseline equation where each digital technology is regressed on the percentage of firms using high-speed broadband connections in a given country-industry cell, one policy variable of interest interacted with the relevant exposure variable, GDP interacted with the same exposure variable as the policy variable and country and industry fixed effects. Regressions are based on a country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016. ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively. ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Source: OECD calculations based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017

Table B.3. Placebo tests

Dependent variable: percentage of firms with >10 employees adopting digital technologies

(1st principal component of ERP, CRM, CC and CC complex)

Placebo variable	Urban concentration		Average firm size by country	
Placebo x knowledge intensity	-0.000589 (0.00158)	-0.00842 (0.00774)	-0.00283 (0.0199)	-0.0444 (0.0328)
1st principal component (skills)		0.362* (0.186)		0.378*** (0.112)
High-speed broadband access (>30 Mbit/s)	2.729*** (0.645)	3.199*** (0.606)	3.033*** (0.700)	3.731*** (0.713)
Observations	372	223	323	172

Note: This tables reports the placebo tests estimates, where each digital technology is regressed on urban concentration measured as the ratio between total population and total land area (1st column) or the average firm size by country (2nd column) interacted with knowledge intensity, the percentage of firms using high-speed broadband connections in a given country-industry cell and country and industry fixed effects. Regressions are based on a country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016. ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Figure B.1. The correlation between knowledge intensity and the share of high-routine employment

Note: The correlation coefficient between knowledge intensity and the share of high routine employment is stands at -0.49 and is found to be statistically significant at the 1% level.

Table B.4. EPL interacted with job turnover

Dependent variable: percentage of firms >10 employees adopting the digital technology

	ERP	CRM	Cloud Computing	Cloud Computing (high)
High-speed internet	0.205*** (0.0624)	0.236*** (0.0648)	0.161*** (0.0543)	0.102** (0.0465)
EPL * Job turnover	-0.00197** (0.000806)	-0.00119* (0.000659)	-0.000594 (0.000562)	-0.000790* (0.000417)
Constant	0.576*** (0.0927)	0.503*** (0.0728)	0.181*** (0.0623)	0.139*** (0.0476)
Observations	413	413	394	376
R-squared	0.854	0.881	0.915	0.853

Note: This table reports baseline estimates of the equation where each digital technology is regressed on the percentage of firms using high-speed broadband connections in a given country-industry cell, employment protection legislation interacted with the rate of job turnover by industry and country and industry fixed effects. Regressions are based on a country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016.

***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Source: OECD calculations based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017.

Table B.5. Capabilities and digital adoption – robustness to a different exposure variable

Exposure variable: share of high routine employment

	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)
I. Organisational capital				
Quality of Management school x share of routine tasks	0.0840*	-0.116***	-0.131***	-0.147***
High-speed broadband access (>30Mbit/s)	0.216***	0.207***	0.134**	0.0365
Observations	369	368	352	336
High performance work practices x share of routine tasks	0.00492	-0.00823**	-0.00995***	-0.0117***
High-speed broadband access (>30Mbit/s)	0.367***	0.247***	0.141*	0.0669
Observations	296	296	280	264
II. Talent Pool				
Percentage of adults with no ICT skills x share of routine tasks	-0.00670*	0.00222	0.00971***	0.00993***
High-speed broadband access (>30Mbit/s)	0.334***	0.210**	0.161**	0.0784
Observations	247	247	248	232
Low skilled in training x share of routine tasks	0.00103	-0.00577**	-0.00875***	-0.00996***
High-speed broadband access (>30Mbit/s)	0.338***	0.333***	0.209***	0.114
Observations	271	271	256	240
High skilled in training x share of routine tasks	0.00107	-0.00388	-0.00735***	-0.00873***
High-speed broadband access (>30Mbit/s)	0.339***	0.329***	0.205***	0.109
Observations	271	271	256	240
Lifelong learning x share of routine tasks	0.00339	-0.00245	-0.00832***	-0.00897***
High-speed broadband access (>30Mbit/s)	0.344***	0.208**	0.149*	0.0655
Observations	247	247	248	232
Skill mismatch x share of routine tasks	-0.00591	0.0130**	0.0108**	0.00825**
High-speed broadband access (>30Mbit/s)	0.319***	0.222**	0.139**	0.0650
Observations	0.314***	0.365***	0.0979***	0.0426**
E-Government x share of routine tasks	0.000298	-0.00329	-0.00363**	-0.00289*
High-speed broadband access (>30Mbit/s)	0.211**	0.205**	0.116*	0.0383
Observations	318	317	301	285

Note: This tables reports estimates of the baseline equation where each digital technology is regressed on the percentage of firms using high-speed broadband connections in a given country-industry cell, one policy variable of interest interacted with the share of high routine employment to proxy for knowledge intensity, and country and industry fixed effects. Regressions are based on a country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016.

***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Source: OECD calculations based on Eurostat, Digital Economy and Society Statistics, Comprehensive Database and national sources, September 2017.

Table B.6. Testing the validity of knowledge intensity as exposure variable**Panel A: Replacing knowledge intensity with firm turnover**

Dependent variable: percentage of firms with >10 employees adopting digital technologies (1st principal component of ERP, CRM, CC and CC complex)

Policy variable	1st principal component (skills)	Quality of Management schools	High performance work practices	Percentage of adults with no ICT skills	Low skilled in training	High skilled in training	Lifelong learning	E-Government	Skill mismatch
Policy variable x turnover	0.00784*	-0.00458	0.000670	-0.00121*	0.00134**	0.000886	0.00151**	0.000659	4.91e-05
High-speed broadband access (>30 Mbit/s)	4.314***	2.555***	3.122***	3.233***	3.806***	3.753***	3.304***	2.702***	2.949***
Observations	429	338	297	308	308	297	363	360	223

Panel B: Adding the interaction between capabilities and firm turnover to the baseline regression

Dependent variable: percentage of firms with >10 employees adopting digital technologies (1st principal component of ERP, CRM, CC and CC complex)

Policy variable	1st principal component (skills)	Quality of Management schools	High performance work practices	Percentage of adults with no ICT skills	Low skilled in training	High skilled in training	Lifelong learning	E-Government	Skill mismatch
Policy variable x turnover	0.00442	-0.00725	0.000442	-0.000851	0.001000	0.000720	0.00109*	0.000415	0.000274
Policy variable x knowledge intensity	0.521***	1.656***	0.0801***	-0.0993***	0.0877***	0.0644***	0.0872***	0.0541***	-0.112***
High-speed broadband access (>30 Mbit/s)	3.323***	2.491***	2.815***	2.888***	3.081***	3.133***	2.715***	2.464***	2.799***
Observations	223	429	338	297	308	308	297	363	360

Note: This tables reports baseline estimates of the baseline equation where each digital technology is regressed on the percentage of firms using high-speed broadband connections in a given country-industry cell, one policy variable of interest interacted with firm turnover (Panel A) and firm turnover and knowledge intensity (Panel B), as well as country and industry fixed effects. Regressions are based on a country-industry data for a set of 25 countries 25 industries (NACE Rev 2, 10-83). To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016.

To maximize coverage, unweighted averages of each variable are used over the time period 2010-2016. ***, ** and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively.

Table B.7. Digital adoption and capabilities: instrumental variable approach

Dependent variable: percentage of firms with >10 employees adopting digital technologies (1st principal component of ERP, CRM, CC and CC complex)

Policy variable	Quality of Management schools	High performance work practices	Percentage of adults with no ICT skills	Low skilled in training	High skilled in training	Lifelong learning	E-Government	Skill mismatch
Policy variable x knowledge intensity	2.350*** (0.310)	0.237*** (0.0416)	-0.164*** (0.0228)	0.148*** (0.0266)	0.168*** (0.0343)	0.159*** (0.0261)	0.124*** (0.0197)	-0.341*** (0.0694)
High-speed broadband access (>30 Mbit/s)	2.462*** (0.492)	2.215*** (0.586)	2.609*** (0.617)	2.523*** (0.575)	2.108*** (0.632)	2.140*** (0.651)	2.138*** (0.591)	2.509*** (0.547)
Observations	429	338	297	308	308	297	363	360

Note: 2SLS estimates of the baseline OLS results shown in Table 3, where capabilities are instrumented with the average level of capabilities in neighbouring countries. Countries are grouped as Southern Europe (Spain, Greece, Italy, Portugal, and Turkey), Central Europe (Austria, Belgium, Germany, France, United Kingdom, Ireland, Iceland, and the Netherlands), Eastern Europe (Czech Republic, Estonia, Hungary, Lithuania, Latvia, Polen, Slovakia, Slovenia) and Northern Europe (Denmark, Finland, Norway, Sweden). The dependent variable the first principal component of the digital technologies considered in this analysis. All specifications include country and industry fixed effects. Robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** significance at the 5% level, * significance at the 10% level.

Table B.8. Digital adoption and capabilities: instrumental variable approach**Panel A: First stage regressions**

Dependent variable	PMR Barriers in services sectors x Turnover		PMR Administrative burden on start-ups x Turnover	
	(1)	(2)	(3)	(4)
Legal Origin (Soviet Union) x Turnover	3.660*** (0.0709)	1.316*** (0.118)	2.203*** (0.0386)	1.213*** (0.0729)
Legal Origin (Germany) x Turnover	3.794*** (0.142)	1.370*** (0.135)	1.798*** (0.0772)	0.824*** (0.0833)
Legal Origin (France) x Turnover	3.854*** (0.0709)	1.590*** (0.107)	2.293*** (0.0386)	1.282*** (0.0661)
Legal Origin (Scandinavia) x Turnover	2.527*** (0.100)	-0.431*** (0.142)	1.459*** (0.0546)	0.270*** (0.0874)
Latitude x Turnover		0.0503*** (0.00218)		0.0202*** (0.00135)
Observations	576	480	576	480
R-squared	0.924	0.974	0.934	0.968

Panel B: Second stage regressions**Dependent variable: percentage of firms >10 employees adopting the digital technology**

Instrument	Legal origin	Legal origin and latitude	Legal origin	Legal origin and latitude
	(1)	(2)	(3)	(4)
High-speed broadband access (>30 Mbit/s)	2.640*** (0.573)	2.774*** (0.663)	2.640*** (0.574)	2.763*** (0.665)
PMR Barriers in services sectors x Turnover	-0.0144*** (0.00520)	-0.0242* (0.0135)		
PMR Administrative burden on start-ups x Turnover			-0.0231*** (0.00864)	-0.0351* (0.0195)
Observations	415	350	415	350
R-squared	0.912	0.912	0.912	0.912

Note: Panel A shows first stage regressions, where the dependent variables are barriers to entry in services sectors (column 1 and 2) and administrative burdens to start-ups (column 3 and 4) interacted with firm turnover. Explanatory variables include dummies for a country's legal origin (France, Germany, Scandinavia, Soviet Union, United Kingdom) as well as a measure for geographic latitude (Barseghyan, 2008). Panel B reports 2SLS estimates of the baseline OLS results shown in Table 4. The dependent variable the first principal component of the digital technologies considered in this analysis. All specifications include country and industry fixed effects. Robust standard errors in parentheses; *** denotes statistical significance at the 1% level, ** significance at the 5% level, * significance at the 10% level.

Table B.9. Univariate regression results: robustness to dropping one sector at a time

	ERP	CRM	CC	CC (complex)
I. Organisational capital				
Quality of Management School X knowledge intensity		Robust	Robust	Robust
High performance work practices X knowledge intensity		Robust	Robust	Robust
II. Talent Pool				
Percentage of adults with no ICT skills X knowledge intensity		Robust	Robust	Robust
Low skilled in training X knowledge intensity		Robust	Robust	Robust
High skilled in training X knowledge intensity		Robust	Robust	Robust
Lifelong learning X knowledge intensity		Robust	Robust	Robust
Skill mismatch X knowledge intensity		Robust	Robust	Robust
E-government X knowledge intensity				
Incentives				
Employment protection legislation X turnover	24_25,27_28,35E_39,41_43,45,49_53,55_56,69_74,77_82	Robust	Robust	Robust
PMR Administrative burdens on start-ups x turnover			24_25	Robust
PMR Barriers in services sectors X turnover		10_12,13_15,24_25,29_30,46,58_60,68	Robust	Robust
Insolvency regime rigidity X financial dependency			Robust	61
Venture capital X financial dependency		Robust	Robust	Robust
Tax incentive support for BERD X Knowledge Intensity		Robust	Robust	
Digital Trade Restrictiveness Index X Share of Computer services as input into sector x	62_63	Robust	24_25,27_28,29_30,61,64,77_82	Robust
Digital Trade Restrictiveness Index X Knowledge intensity		Robust	24_25,26,55_56_58_60,61,77_82	Robust

Note: This table displays the robustness of results displayed in Table 3 and Table 4 (univariate regression results). Sectors listed in this table are those which estimation results are sensitive to, i.e. dropping these sectors implies the loss of statistical significance. Grey areas indicate that estimation results were not significant in the first place.

Table B.10. Univariate regression results: robustness to dropping one country at a time

	Enterprise Resource Planning	Customer Relationship Management	Cloud Computing	Cloud Computing (complex)
I. Organisational capital				
Quality of Management School X knowledge intensity		Robust	Robust	Robust
High performance work practices X knowledge intensity		Robust	Robust	Robust
II. Talent Pool				
Percentage of adults with no ICT skills X knowledge intensity		Robust	Robust	Robust
Low skilled in training X knowledge intensity		Robust	Robust	Robust
High skilled in training X knowledge intensity		Robust	PRT	Robust
Lifelong learning X knowledge intensity		Robust	Robust	Robust
Skill mismatch X knowledge intensity		Robust	Robust	Robust
E-government X knowledge intensity		Robust	Robust	Robust
Incentives				
Employment protection legislation X turnover	CZE, DEU, DNK, EST, FRA, GBR, IRL, ITA, NLD, NOR, PRT, TUR	Robust	IRL, PRT	Robust
PMR Administrative burdens on start-ups x turnover			Robust	Robust
PMR Barriers in services sectors X turnover		BEL, IRL, ITA, POL	Robust	Robust
Insolvency regime rigidity X financial dependency			GBR	GBR
Venture capital X financial dependency		Robust	Robust	Robust
Tax incentive support for BERD X Knowledge Intensity		Robust	FRA, SVK	
Digital Trade Restrictiveness Index X Share of Computer services as input into sector x	DEU	Robust	DEU, EST, GBR, ITA, NLD, NOR, SVK	NLD
Digital Trade Restrictiveness Index X knowledge intensity		Robust	DEU, GBR, HUN, IRL, ISL, ITA, NOR, POL, SVK	NOR

Note: This table displays the robustness of results displayed in Figure X and X (univariate regression results). Countries listed in this table are those which estimation results are sensitive to, i.e. dropping these countries implies the loss of statistical. Grey areas indicate that estimation results were not significant in the first place.

Annex C. Policy initiatives bridging the digital gap

Policies encouraging the diffusion of high-speed broadband: some examples

1. Governments across the OECD take proactive approaches to close existing inter-regional gaps in access to high-speed broadband networks, notably in the form of national broadband strategies or through co-investment (OECD, 2017c).
2. In 2014, EU members endorsed (and meanwhile transposed into national law) the broadband targets set out in the Commission's 'Digital Agenda for Europe — Driving European growth digitally' ('the Digital Agenda'), namely to ensure that, by 2020, all Europeans have access to internet speeds of above 30 Mbps and 50 % or more of EU households subscribe to internet connections above 100 Mbps (European Union Broadband Cost Reduction Directive (2014/61/EU)).³⁶ The directive itself contributes to that aim by proposing various ways to promote competition in communication markets, and reduce costs through the sharing and re-use of existing physical infrastructure.
3. In the context of the EU Digital Strategy, Member States and the Commission also engage in a number of complementary initiatives, including the introduction of: *i*) a toolkit specifically targeted at rural areas, proposing, among other things, the set-up of *Broadband Competence Offices* to foster co-operation across the EU, promote knowledge-exchanges, overcome broadband project hurdles and build capacity in the areas of funding, planning and policy" (EC, 2017a); *ii*) annual European Broadband Awards, one of which in 2017 was awarded to *The Rural Broadband* – a Greek national project, supported by EU funds and implemented via Public Private Partners, which aimed at closing the "broadband gap" between remote, disadvantaged areas and the rest of the country, by providing good connectivity services at affordable costs.
4. Similar initiatives to rollout high-speed broadband are underway in almost all OECD and key partner economies. In New Zealand, for example, over USD 1.48 billion in funding were allocated to communications infrastructure through the Ultra-Fast Broadband (UFB) programme, the Rural Broadband Initiative (RBI) and the Mobile Black Spot Fund (MBSF), in order to bring fibre-to-the-premises broadband with speeds close to 1,000 Mbps by the end of 2022 to 87 % of the population. Meanwhile, the nascent "Indonesian Broadband Plan" aims to provide fixed broadband with speeds of at least 2 Mbps to all government offices, hotels, hospital, schools and public spaces by 2019.

³⁶ Most countries complied with this obligation, however, early 2018 the Commission referred to Bulgaria and the Netherlands to the Court of Justice of the EU for delay in transposing the directive (EC, 2018).

Policies initiatives promoting digital skills

Table C.1. Bridging the digital gap

Country	Initiative
Brazil	Companies are requested to provide free broadband Internet access (wired, wireless or via satellite) to rural schools in order to obtain spectrum for commercial operation of mobile 4G services.
European Union	A range of initiatives with different target groups (e.g. people with cognitive disabilities, or hearing or visually impaired people) is (co-) funded by the European Union ("EU funded projects on Digital Inclusion").
Norway	The program, which is run by the Ministry of Local Government and Modernisation in collaboration with important players in the ICT industry, offers a variety of services to improve the digital competence of specific disadvantaged groups, including, for instance, web based resources for trainers and educators
Mexico	Digital Inclusion Program provides (among other things) training to promote teacher's ICT skills and their ability to apply them in pedagogic activities.
Portugal	Under the "National Strategy for Digital Inclusion and Literacy", the "ICT and Society Network" promotes digital inclusion and literacy of the population at large. As a multi-stakeholder national platform with more than 500 members, this network mobilises regions, cities, municipalities, companies, government, academia, private sector, non-governmental organisations, the media, educators, and citizens, to introduce non-digital citizens to the Internet

Source: All examples are retrieved from OECD (2017b) or OECD (2016)

Table C.2. Policy initiatives in support of vocational training and higher education in ICT

Country	Initiative
Australia	The 'National Innovation and Science Agenda' supports the improvement of gender equity and diversity in STEM (science, technology, engineering and mathematics) fields, including ICT, by increasing opportunities for women.
Czech Republic	The Ministry of Labor and Social Affairs has allocated USD 100 million strategy to increase digital literacy and e-skills development among job-seekers, including displaced workers.
Estonia	The Ministry of Education and Research cooperates with private sector partners and universities to support the 'IT Academy initiative', which promotes the further development of IT higher education through scholarships, summer schools, in-service training and IT curricula development, among other things.
EU	As part of its new 'Skills Agenda for Europe' the Commission asked all Member States to develop national digital skills strategies by mid-2017 and to set up national coalitions to support their implementation. With a view to facilitate the creation of such national strategies, Member State experts have developed a 'shared concept' of challenges to be addressed and potential actions that could form part of a digital skills strategy as well as collected a set of 'best practices'.
Israel	The Welfare and Social Services Ministry of Israel offers training and job placement in ICT specifically for disadvantaged populations. It includes grants to employers who give jobs to trainees.
Luxembourg	Originally from Finland, Rails Girls – a global, non-profit volunteer community – promotes women-only coding classes such as app programming and is supported by the Luxembourg government.
Netherlands	The 'Make IT Work' program retrains highly educated but unemployed people looking for job in ICT for jobs such as software engineering, business analysis, ICT project management and consulting.
UK	Digital degree apprenticeships are offered through a government-backed collaboration between employers and higher education institutions.

Source: All examples are retrieved from OECD (2017b).

The EU data protection framework

5. As digital technologies allow for the acquisition and handling of increasingly large volumes of personal data, privacy concerns have shifted to the forefront of policy making. The European Parliament thus adopted in 2016 a new harmonised set of data protection rules within the European Union, comprising the General Data Protection Regulation (GDPR) (Regulation (EU) 2016/679) applying from 25 May 2018, and the so-called Police Directive (Directive (EU) 2016/680), together replacing an outdated data protection directive from 1995. The GDPR carries provisions that require businesses to protect the personal data and privacy of EU citizens for transactions that occur within EU member states and regulates the exportation of personal data outside the EU. It is considered the most stringent data privacy regulation to date and expected to influence future privacy standards across the globe.

6. Costs of compliance for firms are estimated to be significant, with Members of the Fortune 500 spending a combined \$7.8bn to avoid falling foul of the GDPR, according to the International Association of Privacy Professionals (Financial Times, 2017). These costs come on top of the necessary investment in training to employees, notably as non-compliance can lead to penalties of up to 4% of annual global turnover or a maximum of €20 Million Euro.

7. To offset the increased financial burden placed on firms through this regulation, the cost of services, including for Cloud Computing, provided by European firms (or those dealing with European customer data) is expected to rise in comparison with international competitors. Importantly, however, the state of trust in the digital economy is likely to rise, broadening the potential customer base for European businesses demonstrating their compliance.

Annex D. Digital technologies covered by the analysis

Cloud Computing (CC)

1. Cloud computing allows firms to access computing resources (e.g. servers, databases, software applications, storage capacity, computing power) on a pay-for-use basis over the internet (the ‘cloud’) without incurring the costs involved in building and maintaining the necessary IT infrastructure (Eurostat, 2016). Relative to on-premise IT facilities, cloud computing enables firms, and in particular start-ups and SMEs, to dynamically scale-up (or down) computing resources at any point in time (elasticity of provision) without human interaction (self-service), while paying only for the services that are effectively used (metered service). While it has become a major digital technology, an important impediment recorded by Eurostat was related to the lack of skills: one in three SMEs reported insufficient knowledge of cloud computing to be a limiting factor.¹

2. According to the 2016 Eurostat Digital Economy and Society survey, the most predominant use of cloud computing lies in the use of cloud-based email services (65% of all firms) (e.g. Gmail or Yahoo!), followed by the storing of files in electronic form (62%) (e.g. Dropbox or Google Drive), and the hosting of firms’ databases (44%). While less widespread, cloud computing also allows for more advanced (and credibly more productivity-enhancing) uses such as financial or accounting (32%) and customer relationship (27%) (e.g. Salesforce) management (CRM) software applications, or the provision of computing power in order to run firm-specific business software applications (21%), which are categorised as complex Cloud Computing (complex CC) in this analysis.

3. The effects of cloud computing on firm productivity performance can occur through various channels and depend on the application used. For instance, using cloud document storage services allows several people to share or collaborate on the same document. It thus eliminates the issue of transferring large files and missing on the latest revisions made by someone else. As for CRM systems run over the cloud, their main advantages lie in the possibility to access the system from anywhere in real-time so long as it is connected to the internet, as well as the absence of capacity limits and IT maintenance costs. Aside from increasing number crunching potentials, cloud computing also matches the dissemination of all other technologies described below. For instance, Table A.7 shows that a one percent increase in the share of firms adopting cloud computing is associated with a 0.47 percent increase in the share of firms adopting Customer Relationship Management systems.

Enterprise Resource Planning (ERP)

4. ERP software integrates and automates various functions, such as planning, purchasing, inventory, sales, marketing, finance and human resources, into one system to streamline processes and information across the firm. Its commercialisation began as early as 1972 with German software producer and long-standing market leader SAP

(Gartner, 2017). Instead of maintaining separate databases or spreadsheets monitoring each of the above functions, which would need to be merged to get an overview, ERP systems allow employees to obtain this information from one shared database. For instance, by automatically linking sales orders to the financial systems, the order management department can process orders more rapidly. ERP information can also be shared with external parts of a supply chain, for instance to display to other businesses the current stock of a particular good. Therefore, ERP benefits from network externalities as its usage spreads out across firms along supply chains.

5. Diffusion of ERP systems is limited by the significant amount of time and financial resources required to implement them, as well as their complexity, which in turn requires strong management skills and the provision of adequate trainings for workers.² For this reason, firms generally only adopt ERP systems once they have reached a critical size (Figure A.2). However, cloud computing has facilitated ERP adoption for SMEs, and ERP systems run by the cloud are expected to catch-up with on premise systems over the coming years.

6. While firm-level evidence on the productivity impacts of ERP is scarce, it is generally perceived as cost-reducing and efficiency-enhancing in the long term. For instance, ERP systems can lead to a reduced product development cycle, lower inventories, improved customer service and enhanced coordination of global operations (Beheshti and Beheshti, 2010). Hunton et al. (2002) also show that return on assets, return on investment and asset turnover were significantly better for adopters than for a matched set of non-adopters.

Customer Relationship Management systems (CRM)

7. Customer relationship management refers to the acquisition, analysis and use of knowledge about customers (e.g. vendors, channels partners or any other group of individuals), in order to improve the efficiency of business processes (Bose, 2002). While ERP and CRM systems can overlap in some areas, their core functionalities are different, and businesses can opt for one without the other. Young firms in particular, tend to first adopt CRM systems in order to increase sales before optimising their businesses processes through costly ERP systems, especially as the availability of Cloud Computing has made the adoption of CRM less costly.

¹ Firms that have yet to adopt cloud computing were also concerned about the risk of a security breach, the location of the data and, related to this, the legal jurisdiction and applicable law in the event of a dispute (information retrieved from Eurostat, Digital Economy and Society database).

² ERP implementations can exceed the costs budgeted, take longer than anticipated and deliver less than the promised benefits (Zhang et al., 2005). For example, a 2015 Panorama Consulting report based on 562 implementations globally shows that 21% of firms considered their ERP implementation to be “failed”, although these failure rates are significantly lower than those recorded in the early 2000’s (Griffith et al., 1999; Hong and Kim, 2002; Kumar et al., 2003).