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Going digital: What determines technology diffusion among firms?

Dan Andrews, Giuseppe Nicoletti and Christina Timiliotis

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ABSTRACT/RÉSUME

Going digital: What determines technology diffusion among firms?

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.

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Transformation numérique : Quels sont les déterminants de la diffusion des technologies dans les entreprises ?

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.

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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). This paper identifies a set of structural factors with the potential to overcome these barriers and catalyse the adoption of digital technologies by firms.

2. Indeed, 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). A key question is the extent to which the shortfall in digital diffusion reflects structural weaknesses that can potentially be addressed by public policy. For instance, the well-documented complementarity between technology use and workers' skills (Machin and van Reenen, 1998; Autor et al., 2003; Bartel et al., 2007) can become an obstacle to diffusion where the necessary human capital is in short supply, an area where education and training policies have a clear role to play. 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. Systematic cross-country research on the link between policies, structural factors and adoption of recent digital technologies by firms however, is still scarce. Existing research generally takes either a broad approach by considering the effects of structural factors on ICT investment as a whole (Guerrieri et al., 2010; Cette et al., 2011) or

[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 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.

focuses narrowly on the adoption of specific technologies (see the survey in Oliveira and Martins, 2011).

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. A further contribution is that we also explore the synergies between these two sets of factors in affecting the propensity of firms to adopt.

4. Our working hypothesis is that cross-country differences in digital adoption stem from differences in firms' capabilities and incentives to adopt new technologies. According to the capabilities hypothesis, the complementary intangible investments required for successful adoption of new technologies have become increasingly sophisticated over time. This places an added premium on organisational capital, skills and the efficient allocation of human talents, thus highlighting the importance of policies in the areas of education, training and job matching.

5. Yet, building capabilities is not sufficient if market incentives to adopt new technologies are weak. This is related to a number of factors, including market discipline that makes 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. Together, these factors bring into closer focus policy reforms spurring competitive pressures, business dynamism and efficient resource reallocation.

6. 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) softwares -- for which cross-country industry-level data are available. 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 and could apply to a broader set of technologies. We consider high-speed broadband internet an enabler of these technologies and systematically control for its availability.

7. Indeed, we demonstrate 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

[2] Empirical investigations of the link between digital adoption and productivity are still limited. Recent papers include Bartelsman et al. (2017), Fabling and Grimes (2016) and Dhyne et al. (2017). A forthcoming companion explores in more detail the link between adoption of the same digital technologies covered here and productivity performance.

sophisticated digital applications, and constitutes the backbone of a digital economy.[3]

8. 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.

9. 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 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.

10. Policies aimed at building capabilities within firms 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.

11. 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

[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.

of training for adoption is found to be twice as large for low-skilled than for high-skilled workers, suggesting that policies that encourage the training of low skilled workers are likely to entail a double dividend for productivity and inclusiveness.

12. 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. Policies 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, reforms 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).

13. We also find evidence of significant complementarities in the way factors affecting capabilities and incentives have a bearing for digital adoption. For instance the benefits from improving managerial quality are enhanced if competitive pressures and labour market flexibility (measured respectively by the OECD indicators of product market regulation and of employment protection legislation) are high. These results suggest that digital adoption could be boosted by packaging reforms in these two areas.

14. On the whole, our findings suggest ample scope for product, labour and financial market reforms to amplify the benefits of reforms in education and training systems in speeding up the diffusion of digital technologies across firms. The results, 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. They therefore unveil an important channel through which policy could help close the rising gap between frontier and laggard firms, with potentially significant effects on aggregate productivity developments.

15. Against the background of rising gaps between productivity performance by frontier and laggard firms, the next section discusses the link between the lack of technology diffusion and aggregate productivity weakness. It documents the variability in the adoption of digital technologies across countries and industries and discusses the channels through which structural and policy factors can influence digital technology diffusion and aggregate productivity developments. Section 3 describes the data and provides illustrative evidence on the link between structural factors and rates of digital adoption. Section 4 lays out the empirical framework and reports the empirical results on the influence of our measures of capabilities and incentives on some key digital technologies. Finally, we discuss policy implications and conclude.

2. Productivity, digital technologies and structural influences

2.1. Breakdown of the diffusion machine

16. 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). A key observation is that the (pre-crisis) aggregate productivity slowdown masks a widening performance gap between more productive and less productive firms (Decker et al., 2016; Andrews et al., 2016; Figure 1), which has in turn amplified wage inequality (Berlingieri et al., 2017; Barth et al., 2016; Song et al., 2015). The rising gap in labour productivity is mirrored by similar gap in multifactor-productivity growth (Andrews et al., 2016). This productivity divergence is not just driven by frontier firms pushing the technological boundary outwards. Instead, firm-level econometric evidence suggests that the OECD-wide pace of technological convergence – whereby laggard firms can catch-up based on the adoption of a larger stock of unexploited technologies – has declined by around one-third since the late 1990s (Andrews et al., 2016). 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 frontier – a breakdown of the diffusion machine (OECD, 2015; Andrews et al., 2016).

17. According to the capabilities hypothesis, 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 ideas.[4] In this regard, it is particularly significant that laggard firms fell further behind in market services (Figure 1, Panel B), where intangibles and tacit knowledge are becoming ever more important and the premium on capabilities should be highest.

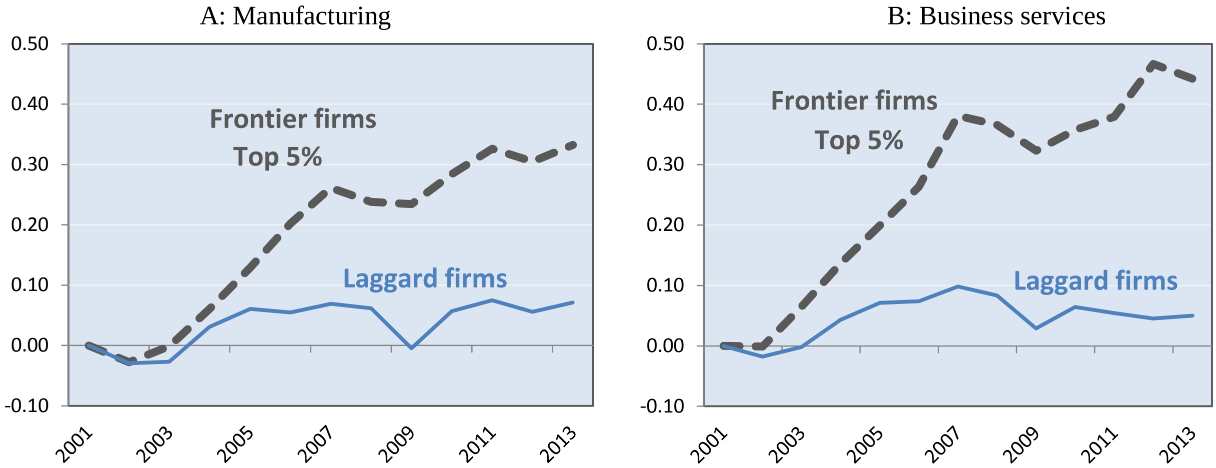
18. But the market incentives for technological adoption may have also weakened, as adjustment frictions that rein in the creative destruction process have increased. A slew of micro-level evidence suggests that it has become relatively easier for weak firms that do not adopt the latest technologies to survive, including: *i*) the declining propensity for high productivity firms to expand and low productivity firms to downsize (Decker et al., 2017); *ii*) declining firm entry, implying less indirect pressure on incumbent firms to adopt (Criscuolo et al., 2014; Hathaway and Litan, 2014); and *iii*) 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). As business dynamism has stalled and scarce resources have become increasingly trapped in redundant activities, it has arguably become more difficult for both new entrants and incumbent firms to adjust their labour force to meet new conditions and to access the capital required for adoption.

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

19. These findings are significant in light of aggregate level analysis which suggests that while adoption lags for new technologies across countries have fallen over time, there has been a divergence in long-run penetration rates once technologies are adopted by frontier firms (Comin and Mestieri, 2013).[5] In other words, 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, and many existing technologies may remain unexploited by a non-trivial share of firms in an economy. Against this backdrop, research into the barriers to technology adoption is warranted.

Figure 1. The divergence in labour productivity growth

Average labour productivity across each 2-digit sector (log, 2001=0)



Note: The global frontier group of firms is defined by the top 5% of companies with the highest labour productivity levels within each 2-digit industry. Laggards capture all the other firms. The vertical axes represent log-differences from the starting year. For instance, the frontier in manufacturing has a value of about 0.3 in the final year, which corresponds to approximately 30% higher in productivity in 2013 compared to 2001. Average values are shown across 24 OECD countries and 22 manufacturing and 27 market services industries over the time period 2001-13. Services refer to nonfinancial business services.

Source: Andrews, D. C. Criscuolo and P. Gal (2016)

2.2. Key technologies

20. A wide range of digital technologies has emerged over the past decade, forming an ecosystem that holds the potential to generate significant productivity gains. 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 technologies are still scarce. Turning to digital technologies for which comparable adoption rates are available for a large set of

[5] For instance, Comin and Mestieri (2013) 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.

European countries, however, 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. Indeed, McKinsey Global Institute (2018) estimates that overall Europe operates at only 12 percent of digital potential, in comparison with 18 percent for the United States.

21. Indeed, Figure 2 shows that while virtually all 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 given technology greatly differ across counties 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[6] compared to 15% of the Hotel and Restauration sector.[7]

22. We focus on two broad digital technologies: cloud computing (CC) and front or back office applications. In turn, 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 Box 1 for a detailed description of each technology). We consider broadband high-speed internet - a prerequisite to effectively use almost any digital technology – an enabling infrastructure, and systematically control for its availability. The selection of technologies was based on both their expected within-firm productivity-enhancing effects and their potential to diffuse these productivity benefits across firms due to spillovers.[8] Indeed, the aggregate benefits of some of these technologies (e.g. ERP) can be boosted by network effects as they diffuse across firms along supply chains.[9]

[6] ISIC Rev.4 sector 61, Manufacture of electronic and optical products

[7] ISIC Rev.4 sector 55-56, Accommodation and Food and beverage service activities

[8] 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.

[9] Hard evidence on these firm-level effects is scarce, not least due to the sensitive nature of the information necessary for the investigation, but ongoing work relying on more aggregate data is devoted to exploring the productivity effects of the same technologies.

Box 1. Digital technologies covered by the analysis

Cloud Computing (CC)

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]

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.

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)

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.

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.

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)

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.

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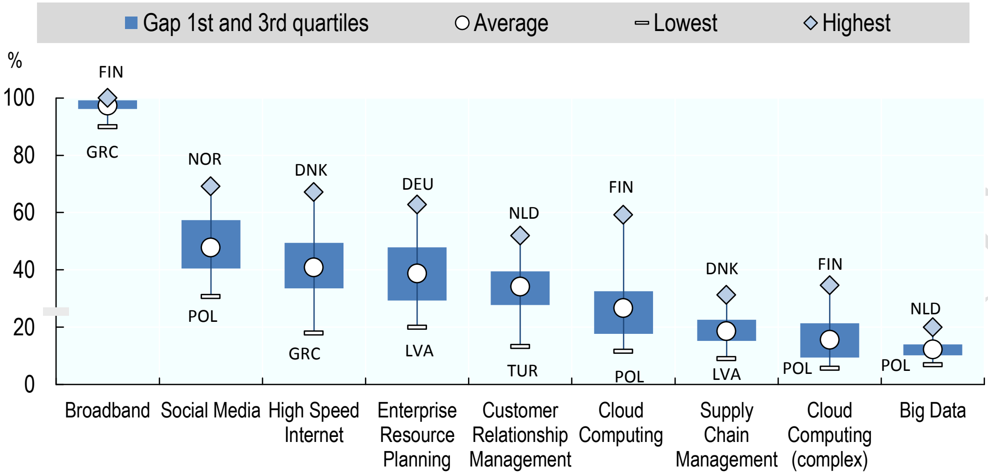
[1] Firms that have yet to adopt cloud computing were also concerned about the risk of a security breach, the location of the data and, related to this, the legal jurisdiction and applicable law in the event of a dispute (information retrieved from Eurostat, Digital Economy and Society database).

[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).

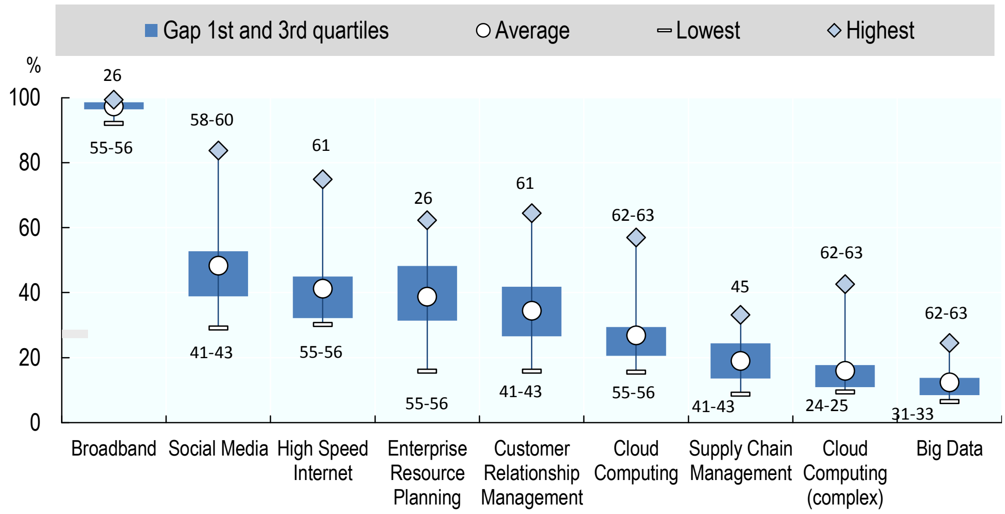
Figure 2. The diffusion of digital technologies is uneven across countries and industries

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)

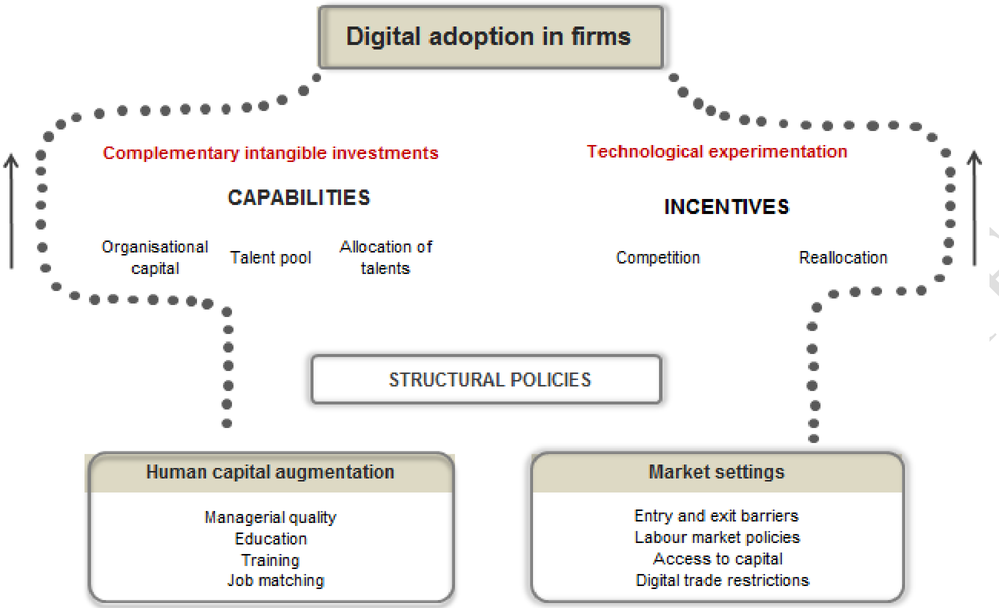
23. The varying degrees at which digital technologies have diffused across countries seem surprising at first, considering the marginal costs of adopting most technologies displayed above are either close to zero (e.g. for social media), or have plummeted over the past decade (e.g. for cloud computing). Taken together, the observed patterns thus suggest the presence of important structural elements impeding the widespread diffusion of digital technologies across countries. One key enabler is the availability of digital infrastructures – including widely available accessible communication network and services – which in turn can promote the diffusion of digital technologies and *inter alia* aggregate productivity growth (Égert et al., 2009; Falck and Wiederhold, 2015; Fabling and Grimes, 2016). While most firms appear to have broadband connections, wide cross-country and cross-sector differences remain in the adoption of high-speed internet (Figure 2), which is crucial for an effective use of the digital technologies considered in this paper. [10] Given the importance of high-speed broadband internet for the take up of digital technologies, throughout the analysis below we control for differences in the availability of this key infrastructure across countries and industries. Even so, these differences can only partially account for the wide variability of digital technologies across countries and here is where differences in capabilities and incentives enter the picture.

2.3. Structural and policy influences

24. The stylised framework depicted in Figure 3 shows some of the channels through which structural and policy factors can drive cross-country differences in the adoption of digital technologies. We conjecture two broad channels: i) firm capabilities, which underpin the complementary intangible inputs required for adoption; and ii) the market environment in which firms operate, which shapes the incentives for firms to experiment with digital technologies. Factors that shape firms' capabilities or incentives to adopt could affect the diffusion of digital technologies directly, or indirectly by influencing the productivity returns to investments in digital technologies (which would likely feed back into the original decision to adopt). We discuss below the role played by these factors in affecting digital adoption by firms and the corresponding proxies we use in the empirical analysis. As shown in Table 1 and more in detail in the Annex, there is wide variability across countries in structural factors and policies that affect capabilities and incentives (see Table A.3).

[10] 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 3. Structural channels influencing digital adoption



2.3.1. *Capabilities and digital adoption*

25. The challenging transition of an economy based on tangibles to one based on intangibles (or ideas) can only succeed if firms have access to the right set of *capabilities*. The transition at the firm level depends on two main factors: (*i*) strategic decisions and the ability to implement them, and (*ii*) the talent pool and the ability to upgrade it. The first factor requires high quality management and managerial practices. The second requires a pool of skilled workers that include ICT specialists, whose expertise is (often) fundamental to deploying and managing digital technologies, as well as more broadly diffused ICT skills among job seekers and workers, and the ability to improve these skills in accordance with technological developments.

Organisational capital

26. Leadership skills, up-to-date managerial practices and innovative working arrangements are a necessary condition for the successful implementation of new technologies. Indeed, there is a robust positive relationship between investment in organisational capital and the returns from ICT investment (Brynjolfsson et al., 1997; 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.

27. To proxy for cross-country differences in managerial practices, we adopt two indicators, which crucially are available for a large number of countries.[11] First,

[11] 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

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.[12] 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.[13]

28. 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.[14] 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).[15]

Skilled labour

29. The diffusion of digital adoption and the ability to fully harness its productivity benefits in full require a pool of workers with a sound level of generic ICT-skills, out- and on-the-job programmes to provide and maintain such skills, and the appropriate matching of skills to jobs. We use several indicators to measure cross-country differences along these dimensions of the talent pool.

30. The precondition for acquiring digital skills is mastering generic skills (literacy, numeracy, and problem-solving), which provide a basis for learning fast-

relatives or friends without regard to merit; 7=mostly professional managers chosen for merit and qualifications]".

[12] 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.

[13] 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.

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

[15] 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).

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).[16] 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).

31. Policy-wise, the promotion of digital literacy 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.[17] At later ages broader digital strategies also involve lifelong learning, another indicator we use in the empirical analysis, hinging inter alia on continuous vocational training, adult learning and on-the-job training. Moreover, policies to encourage ICT use by individuals through the provision of e-government services can help fostering citizens' affinity to digital technologies. 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. 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).

32. 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), 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).

33. Several countries have taken explicit measures to remedy for the gap between training participation rates of the low and high-skilled, for instance by

[16] 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).

[17] 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).

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).[18] While the design of such financial incentive schemes is crucial for minimising distortions and maximise their economic and distributional benefits (OECD, 2017d),[19] facilitating and encouraging generic and ICT training to low-skilled non-ICT workers can have an impact on the ability to adopt digital technologies.

Allocation of talent

34. 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. 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. 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).[20] 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.

[18] See EC (2015) and OECD (2017d).

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

[20] 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.

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.

2.3.2. Incentives and digital adoption

35. The incentives of firms to adopt leading technologies are closely linked to the extent of competitive pressures in the economy. 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 (Figure 1). 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.[21]

36. The margins through which digitalisation is propagated onto aggregate growth suggest to focus on policies that are relevant for firm entry and exit and the efficient reallocation of resources across incumbent firms.

[21] 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).

Entry and competition

37. Key policy areas fostering competition, notably through the entry side, include:

- Administrative burdens on start-up firms: structural policies that do not unduly inhibit the 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. Accordingly, we examine this link, although remaining cross-country differences in administrative burdens on start-up firms – at least according to OECD indicators – are now relatively modest (Figure A.6, Panel A).[22]

- Barriers to entry in competitive services (Figure A.6): 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, reforms targeting these impediments to competition are key (Andrews et al., 2016). Effects of service sector reforms are amplified when services additionally feed into other sectors downstream as intermediates.

- Open digital markets (Figure A.10): 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. The European Centre for Internal Political Economy (ECIPE) Digital Trade Restrictiveness Index (DTRI) captures the extent to which countries obstruct digital trade, e.g. through tariffs on digital products, restrictions on digital services and investments, restrictions on the movement of data, and restrictions on e-commerce.[23] Restrictions on the movement of data also depend on data protection regulations, which are common in many regions (see Box 3 for Europe).

Reallocation and exit

38. Some of the above mentioned policies are also themselves relevant on the reallocation side, in particular well-designed product market regulations (particularly those affecting firm entry and market services). Other policy areas promoting a healthy creative destruction process by facilitating the exit of unproductive firms and the efficient reallocation of labour and capital include:

- Employment protection legislation (EPL; Figure A.7): EPL regimes imposing heavy or unpredictable costs on hiring and firing can also slow down the reallocation process (Bassanini et al., 2009; Andrews and

[22] 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).

[23] 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).

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., 2010; 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, 2003; Wasmer, 2006).

- The depth of risk capital markets: to the extent that venture capitalists help bridge the financing gap that arises from the fact that young firms lack internal funds and a track record to signal their "quality" to investors (Hall and Lerner, 2009) risk capital markets affect firm entry and the ability of successful new entrants to grow. Cross-country differences in the availability of risk capital are significant (Figure A.8) and are positively related to the efficiency 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 (Figure A.6): 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, *inter alia* by incentivising experimentation and freeing up resources to underpin digital uptake by successful firms.

39. While the stylised framework in Figure 3 implies that market reforms affect digital adoption by incentivising 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 EPL is 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 in firms to improve managerial capital (e.g. by hiring better managers) and put pressure on management to improve their performance.

40. 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. 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). Since no comparable cross-country data quantifying the effect of cyberattacks is available to date, this aspect exceeds the scope of this report.

Box 2. The EU data protection framework

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.

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 comes 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.

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.

3. Digital technologies: data and stylised facts

3.1. The data on technology usage

41. The data on digital technology usage are drawn from the Eurostat "*community survey on ICT usage and e-commerce in enterprises*" and has 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 policy 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.

42. The sub-set of indicators covered by our analysis were selected from a list of several hundred variables available in the Eurostat dataset, based on their potential complementarity, their likely productivity-enhancing effects as well as to maximise cross-country, cross-industry coverage (see Box 1 for detail on each of the selected technologies). 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 the technologies – such as the complexity of ERP systems – which prevent their wider dissemination.[24] Correlations across use of different digital technologies are thus not as high as one might expect (see Table A.8).

43. 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 procedure is based on the observation that, within each country-industry cell, variability over time was limited over the period considered (Table A.4).The resulting cross-sectional sample therefore covers variation across 25 countries and 25 industries.

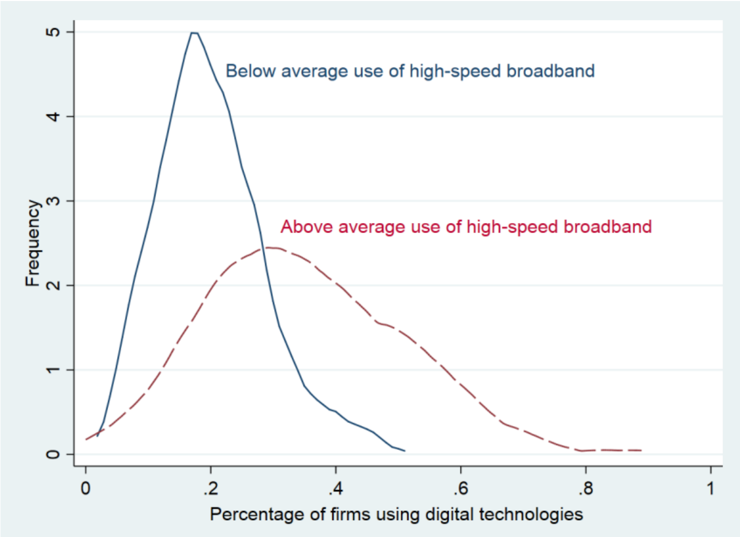
3.2. Digital adoption and structural factors: some suggestive evidence

44. Access to reliable and fast broadband connections constitutes the backbone of a digital society and economy. Indeed, among the technologies considered in this analysis, none would function effectively without the internet.[25] 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. Indeed, Figure 4 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).

[24] 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.

[25] 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.

Figure 4. 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 (high)) 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.

45. 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 the previous section, adoption rates are also likely to be affected by structural policies that enhance complementary human capital (*capabilities*) or business dynamism (*incentives*). Illustrative evidence of this link is provided in Figure 5 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.

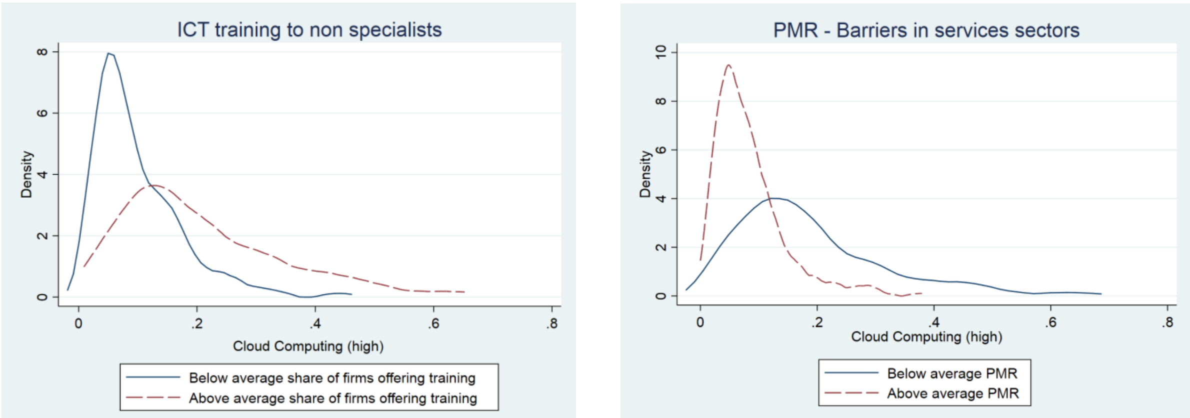
46. For instance, adoption of complex CC across industries appears to be higher in countries that have an above average level of ICT training for non-ICT workers and lower barriers to competition in services sectors. This is consistent with the strong complementarity between digital technologies and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

47. 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 areas requiring education towards STEM areas).

Figure 5. Structural policies and the diffusion of complex cloud computing

A. The adoption of complex CC is higher when ICT training is provided to workers

B. The adoption of complex CC is higher when barriers to services sectors are low



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.

4. The influence of capabilities and incentives on digital adoption

4.1. Empirical approach

48. 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 potentially causal effects of country-wide factors 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. The implicit assumption behind this approach is 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).

49. Accordingly, we based our analysis on three key sets of assumptions, which have been exploited in a range of recent OECD analyses[26]:

- industries that are intrinsically more knowledge intensive – measured as the share of labour compensation for personnel with tertiary education – are more exposed to policies that affect managerial quality and the level of workers' skills;

[26] 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.

- 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 exposed to policies that raise barriers to the entry of firms or impede the adjustment of the workforce; and
- industries that are more dependent on external finance – measured as in Rajan-Zingales (1998) – are more exposed to policies that affect the availability of private equity and the efficiency of exit mechanisms, since greater reliance on external creditors increases the likelihood of having to go through a formal insolvency process;
- 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 exposed to policies affecting the openness of markets to trade with digital products and services.

50. 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).[27] 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.

51. We also test for the robustness of the results to our assumptions by alternative exposure variables. Notably we replace the knowledge intensity exposure variable with the sectoral share of high routine-tasks (Marcolin et al., 2016) which is significantly not perfectly correlated with our measure of knowledge intensity (see Figure B.1.). For labour market policies we also use layoff rates (defined as the percentage ratio of annual layoffs to total employment) instead of firm turnover (see Table B.2).

52. The key hypothesis is that industries in the treatment group should be disproportionally more affected than other industries (i.e. the control group) 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.

53. 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.

[27] Knowledge intensity by industry is drawn from OECD (2013a), firm turnover by industry is drawn from Bartelsman et al. (2013), 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.

54. The resulting baseline specification is as follows:

$$Adopt_{c,s}^{j} = \alpha + \beta_1 BB_{c,s} + \beta_2 Pol_c * Exp_s + \delta_c + \delta_s + \varepsilon_{c,s}$$, 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 policy or structural factors that affect incentives or capabilities 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

55. As discussed in section 2, we consider a number of proxies for capability and incentive factors (see Table 2). All of them are country-wide. Further details on variable definitions and sources are provided in Appendix A.

Table 2. Proxies for capability and incentive factors

	Policy variable	Source of policy 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.

4.2. Results

56. We estimate three versions of our digital adoption model, first testing the influence of capability and incentive factors separately and one by one (Table 3, Table 4), then testing the joint influence of pairs of capability and incentive factors (Table 5) and lastly, for a reduced set of variables, checking for potential policy complementarities between both sets of structural factors (Table 6), which involves adding an interaction of capabilities and incentive indicators to the baseline model. In some cases, we also provide results that summarise the effects of capabilities and incentives on digital adoption by using the first principal component of the

technologies covered in our analysis as the dependent variable.[28] 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.

57. 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.

4.2.1. The influence of capabilities on digital adoption

58. 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 for 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.

59. Turning to the individual capabilities, results suggests 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.

60. 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.[29] 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.

61. 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 6). Increasing the

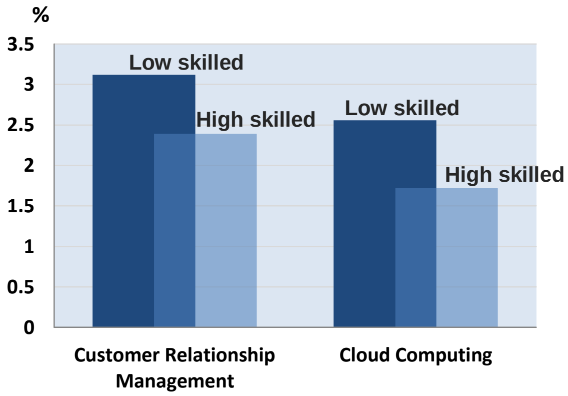
[28] Identical results are also found when the first principal component of the wider set of technologies shown in Figure 2 is used instead.

[29] To some extent in turn this reflects some co-variation of these variables across the country-industry dimension.

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 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 6. 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

62. 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).

63. As shown in Table B.3 results are robust to replacing knowledge intensity with the sectoral share of high-routine tasks (in the US) as an exposure variable. Also, results are broadly robust to dropping one country or sector at a time (see Table B.4 and Table B.5).

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)	**1st principal component**
A. Capabilities					
Principal Component Analysis					
1st 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 (except in the case of ICT training which is at the country-industry level) 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

4.2.2. Policies affecting the incentives to adopt

64. Estimates of the influence of policies affecting market incentives 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 policies that ease frictions on the reallocation process, strengthen competitive pressures and stimulate financial market development.

Entry and competition

65. In line with our expectations, lower administrative burdens on startups are estimated to significantly 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. Lower barriers to entry in services sectors have similar effects on adoption rates of both cloud computing and CRM: this may reflect both stronger market incentives to adopt in these 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. Barriers to digital trade have a similar negative impact on the adoption of all technologies, reflecting reduced competitive pressures and more difficult access to crucial inputs.

Exit and reallocation

66. 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. Similar effects, though at a weaker level of significance, are found for all technologies when the effect of EPL is tested in sectors with high relative to low job layoff rates (see Table B.2). 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.

67. 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.

68. 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.

4.2.3. Pairwise regressions and economic significance

69. 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.[30] 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. 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.

70. 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.

71. 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.

[30] 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)	1st 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	0.00147	-0.00195*	-0.00216**	-0.00399***	-0.0320***
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	-0.0371**	-0.0769***	-0.0323*	-0.0497**	-0.607**
High-speed broadband access (>30Mbit/s)	0.204***	0.228***	0.174***	0.102**	2.447***
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	-0.00253	0.526***	0.348***	0.547***	5.298***
High-speed broadband access (>30Mbit/s)	0.239***	0.217**	0.194***	0.0830	2.538***
Observations	290	289	290	270	265
Tax incentive support for BERD X Knowledge Intensity	-0.136	0.656**	0.554***	0.241	3.632
High-speed broadband access (>30Mbit/s)	0.253***	0.267***	0.185***	0.124**	2.782***
Observations	411	411	390	370	364
Insolvency Regime Rigidity x Financial Dependency	0.0211	-0.0145	-0.0482**	-0.0375**	-0.392**
High-speed broadband access (>30Mbit/s)	0.214***	0.267***	0.191***	0.137***	2.845***
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)
Incentive	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***
Incentive	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***
Incentive	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***
Incentive	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***
Incentive	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***
Incentive	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***
Incentives	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***
Incentive	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***

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)
Incentive	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***
Incentive	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***
Incentive	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***
Incentive	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***
Incentive	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***
Incentive	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***
Incentive	-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***
Incentive	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 7 and Figure 8.
***, ** 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

72. 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 7 and Figure 8 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 A.4 for details). As already mentioned, calculations are based on the most conservative estimates, accounting for both incentives and capabilities. Effects that are statistically not significant are reported as nil.

73. 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).

74. 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 2). 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.

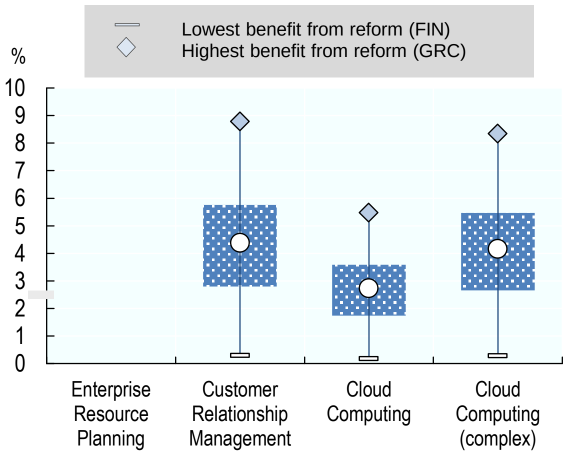
75. The estimated gains in adoption of exposed versus non exposed industries that are implied by policy reforms affecting incentives are somewhat less spectacular but still large, especially in view of the fact that some of them (e.g. reducing administrative burdens or reforming insolvency regimes) could 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).

76. On the whole, these 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.

Figure 7. Economic significance (Capabilities)

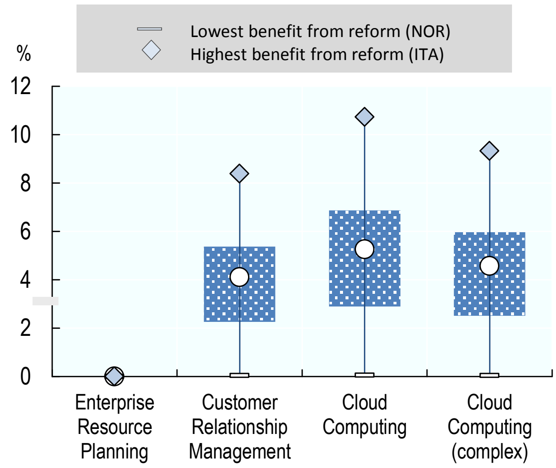
A: Increase in digital adoption rate from increasing the diffusion of HPWP to maximum level (DNK)

Differential impact between industries with high and low knowledge intensity



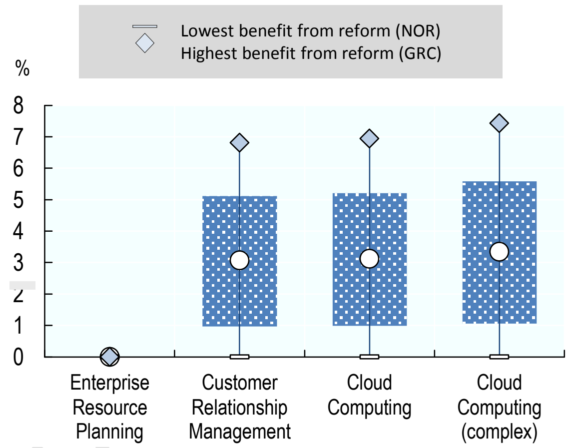
B: Increase in digital adoption rate from increasing the share of citizens using e-government services to maximum level (ISL)

Differential impact between industries with high and low knowledge intensity



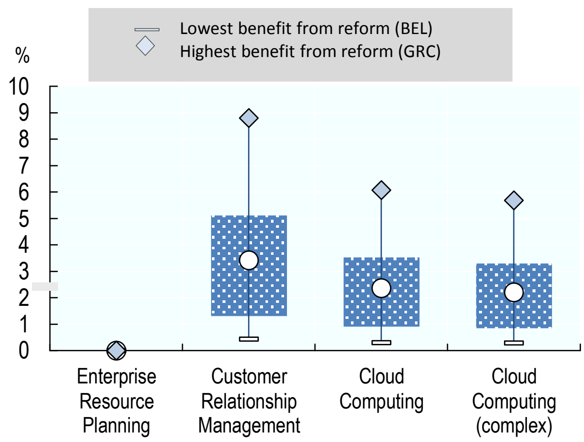
C: Increase in digital adoption rate from increasing the percentage of low skilled workers in training to maximum level (DNK)

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

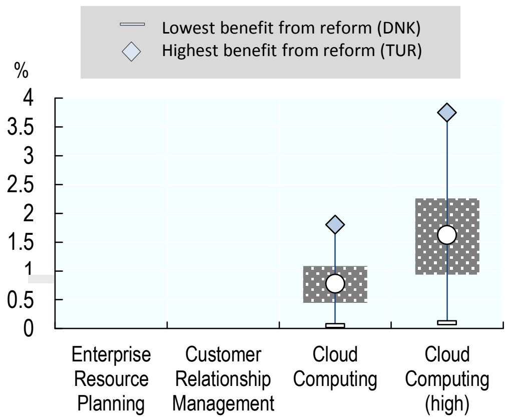


Notes: These graphs show the ceteris paribus increase in digital adoption rates from increasing the quality of management school (Panel A), the percentage of low-skilled in training (Panel C) to sample maximum, or decreasing the share of adults with no ICT skills (Panel B), or the percentage of workers 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 8. Economic significance (Incentives)

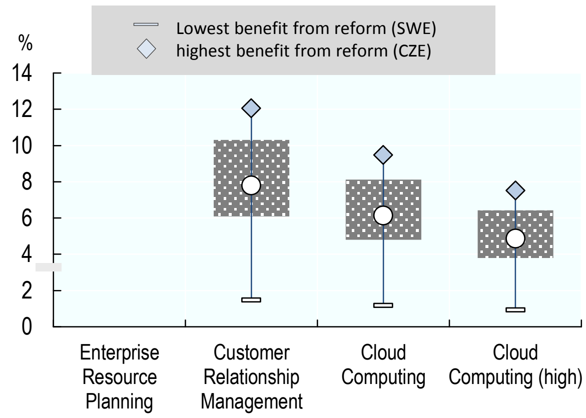
C: Increase in digital adoption rate from decreasing administrative burdens for start-ups to minimum level (NLD)

Differential impact between industries with high and low firm turnover



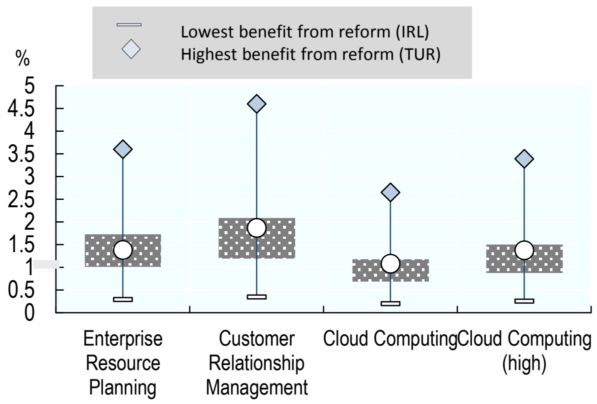
B: Increase in digital adoption rate from increasing the share of venture capital (as a percentage of GDP) to maximum level (DNK)

Differential impact between industries with high and low external financial dependency



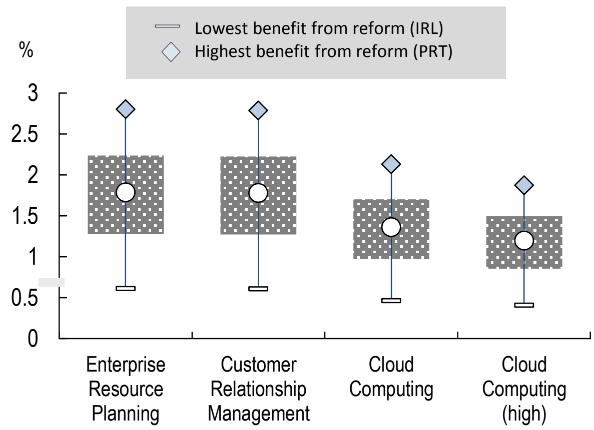
D: Increase in digital adoption rate from easing barriers to digital trade to minimum level (ISL)

Differential impact between industries with a high and low share of intermediate computer services inputs



A: Increase in digital adoption rate from reducing EPL to minimum level (GBR)

Differential impact between industries with high and low firm turnover



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.

5. Policy complementarities

77. 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, 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 2.3.2) 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.

78. 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.

79. 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 policies aimed at imposing market incentives and firm capabilities.

80. 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 9). 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)	1st principal component
A: Administrative Burdens to Startups					
High-speed internet	0.353***	0.251***	0.170**	0.116**	2.784***
	(0.0648)	(0.0742)	(0.0673)	(0.0517)	(0.660)
HPWP* Knowledge Intensity	8.26e-06	0.0116***	0.0121***	0.0163***	0.156***
	(0.00375)	(0.00256)	(0.00297)	(0.00282)	(0.0308)
HPWP* Knowledge Intensity* Administrative Burdens to Startups (PMR)	-0.00204	-0.00164	-0.00583***	-0.00696***	-0.0684***
	(0.00221)	(0.00234)	(0.00211)	(0.00186)	(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***	0.236***	0.161**	0.0961*	2.647***
	(0.0658)	(0.0739)	(0.0666)	(0.0509)	(0.650)
HPWP* Knowledge Intensity	-0.00132	0.0160***	0.0102***	0.0170***	0.142***
	(0.00378)	(0.00374)	(0.00306)	(0.00318)	(0.0408)
HPWP* Knowledge Intensity *Digital Trade Restrictiveness Index	-0.00521	-0.0368**	-0.0254**	-0.0453***	-0.327*
	(0.0172)	(0.0169)	(0.0123)	(0.0143)	(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***	0.255***	0.174**	0.119**	2.820***
	(0.0650)	(0.0755)	(0.0674)	(0.0522)	(0.661)
HPWP* Knowledge Intensity	0.00368	0.0225***	0.0200***	0.0230***	0.244***
	(0.00669)	(0.00536)	(0.00575)	(0.00510)	(0.0532)
HPWP* Knowledge Intensity * Employment Protection Legislation	-0.00244	-0.00525**	-0.00616***	-0.00611***	-0.0691***
	(0.00251)	(0.00238)	(0.00234)	(0.00199)	(0.0206)
Observations	384	385	364	343	338
R-squared	0.863	0.893	0.909	0.870	0.921

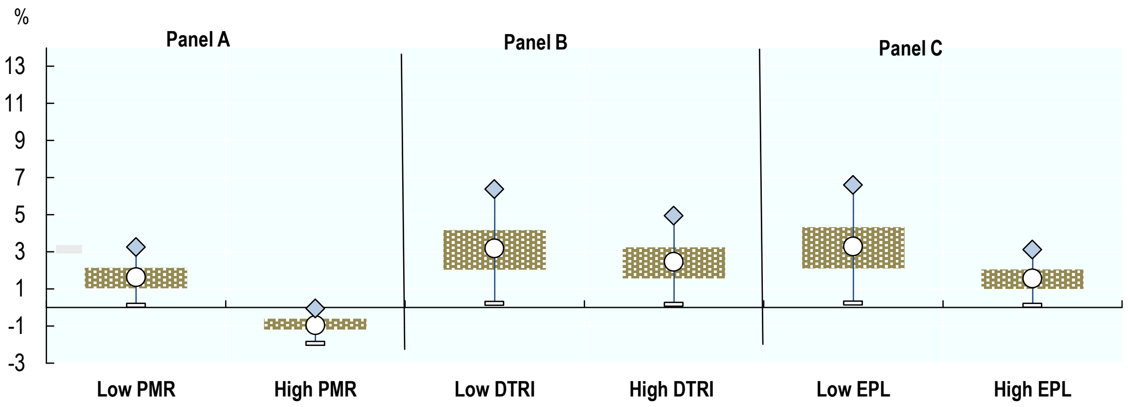
Note: This table reports estimates of a model specification in which each digital technology is regressed on the percentage of firms using high-speed broadband connections in a given country-industry cell, the prevalence of high performance work practices interacted with knowledge intensity only, and 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.

***, ** 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 9. 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 (DNK), 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.

6. Policy implications and conclusion

81. 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). Accordingly, this paper exploits a novel cross-country industry-level dataset to explore the structural barriers to digital adoption in firms. The results are consistent with the idea that digital adoption in firms is supported by three overriding factors. First, improving the roll-out of high quality broadband infrastructure is complementary to the adoption of more sophisticated digital applications. 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.

82. 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. But building capabilities is 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. 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.

83. 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 supressing 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 explore how the same structural and policy factors shape the productivity returns from investments in digital technologies.

84. 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".

85. 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.

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Annex A. Description of the data and variables used

Table A.1. Description of variables and sources

	Description	Coverage	Source	Link
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/data/dataset/V1eagdIL3oK5ZPzkT0PCZw
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	(data published in 2018)	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
Capabilities				
Quality of	Quality of management schools, 1-7(best)	Average	The Global Competitiveness	http://reports.weforum.org/gl

Management school	(Weighted average 14-15)	2014-15	Report 2015–2016 (2016), World Economic Forum	obal-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)	http://dx.doi.org/10.1787/888933273688
Lifelong learning	Share of adults participation in lifelong learning	Average 2012;2015	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
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)	
External Financial Dependency	Industry external finance dependency (USA)	1980's	Rajan, R. and L. Zingales (1998)	
Knowledge Intensity	Share of labour compensation of personnel with tertiary education (USA)	1995-2000	OECD (2013)	http://dx.doi.org/10.1787/9789264193307-en
Job Turnover	Industry turnover rate (job turnover)	2001-2003	Bassanini, Nunziata and Venn (2009)	
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).	

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

Variable	Year	Observations	Mean	Std. Dev.	Min	Max
High-speed broadband connections	2014	554	0.292277	0.179788	0	0.844943
High-speed broadband connections	2015	569	0.341266	0.192667	0	0.92
High-speed broadband connections	2016	578	0.386863	0.196471	0	1
ERP	2010	634	0.232888	0.159553	0	0.869444
ERP	2012	568	0.254056	0.1543	0	0.81877
ERP	2013	567	0.297989	0.165386	0	0.8075
ERP	2014	554	0.335103	0.184815	0.009897	1
ERP	2015	548	0.366436	0.183516	0.032499	1
CRM	2010	610	0.305617	0.196722	0	1
CRM	2014	565	0.298077	0.176049	0.016865	1
CRM	2015	573	0.324962	0.171728	0.028658	1
Cloud Computing	2014	574	0.204861	0.156336	0	0.886937
Cloud Computing	2015	346	0.215508	0.164838	0.003937	0.824419
Cloud Computing	2016	501	0.241223	0.168425	0	0.854624
Cloud Computing (high)	2014	550	0.113735	0.107308	0	0.666894
Cloud Computing (high)	2015	321	0.119671	0.110832	0	0.64928
Cloud Computing (high)	2016	552	0.134412	0.122234	0	0.675505

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

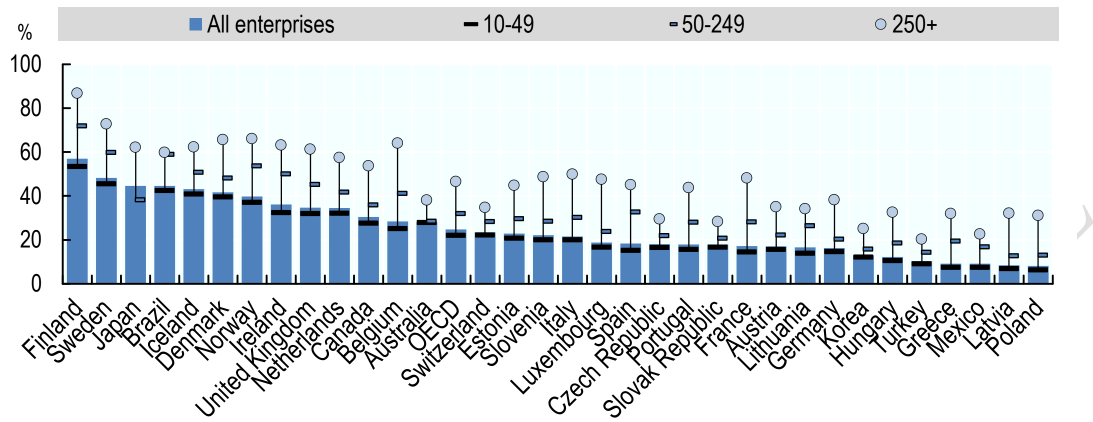
Table A.5. Average adoption rates by industry (2010-2016)

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

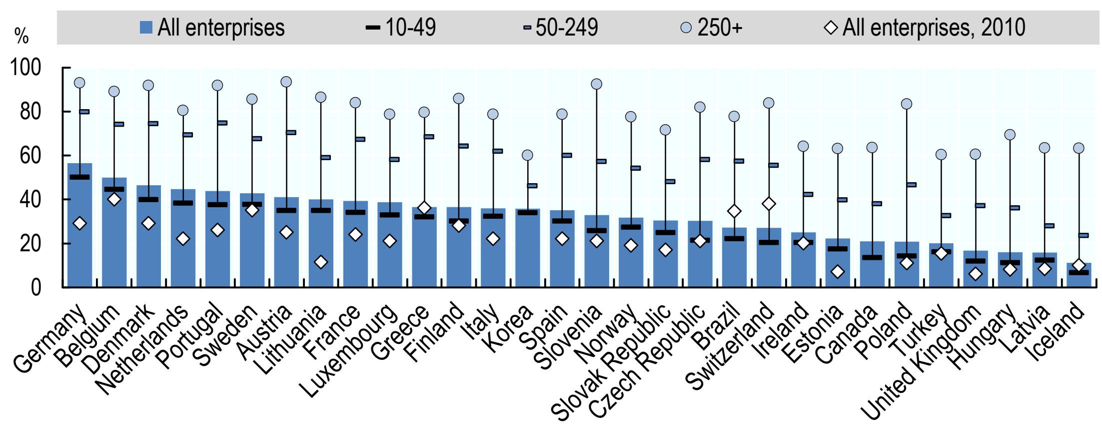
As a percentage of enterprises in each employment size class.



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***	0.248***	0.178***	0.110***
	(0.0477)	(0.0425)	(0.0378)	(0.0343)
Constant	0.372***	0.385***	0.112***	0.0504**
	(0.0303)	(0.0264)	(0.0204)	(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***	0.151***
	-0.0646	-0.0529
Cloud Computing	**0.173****	**0.472*****
	-0.081	-0.0607
Constant	0.345***	0.336***
	-0.0296	-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

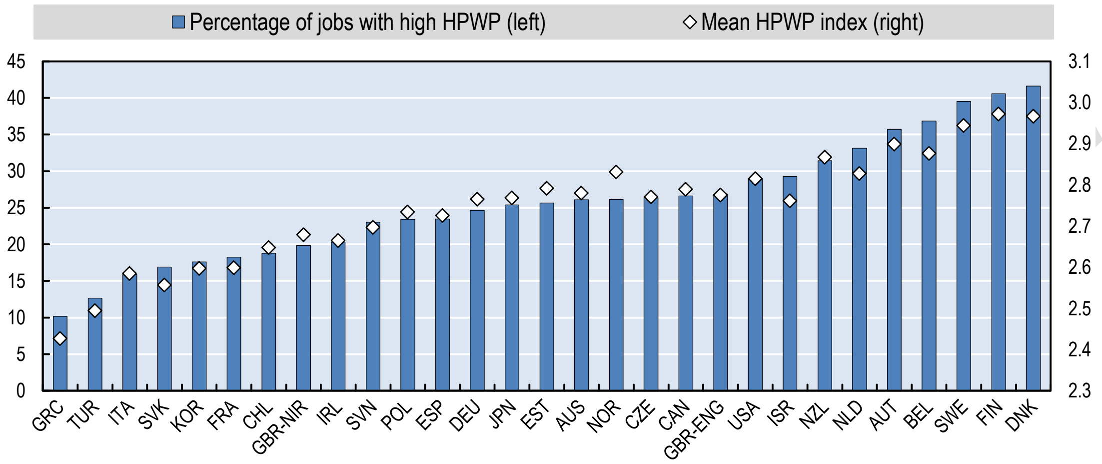
	Broadband	High-speed broadband	Cloud Computing	Cloud Computing (complex)	ERP	CRM
Broadband	1					
High-speed broadband	0.098**	1				
Cloud Computing	-0.0079	0.2252***	1			
Cloud Computing (complex)	-0.1074**	0.1598***	0.7279***	1		
Enterprise Resource Planning	0.1599***	0.206***	0.1257***	0.0656	1	
Customer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

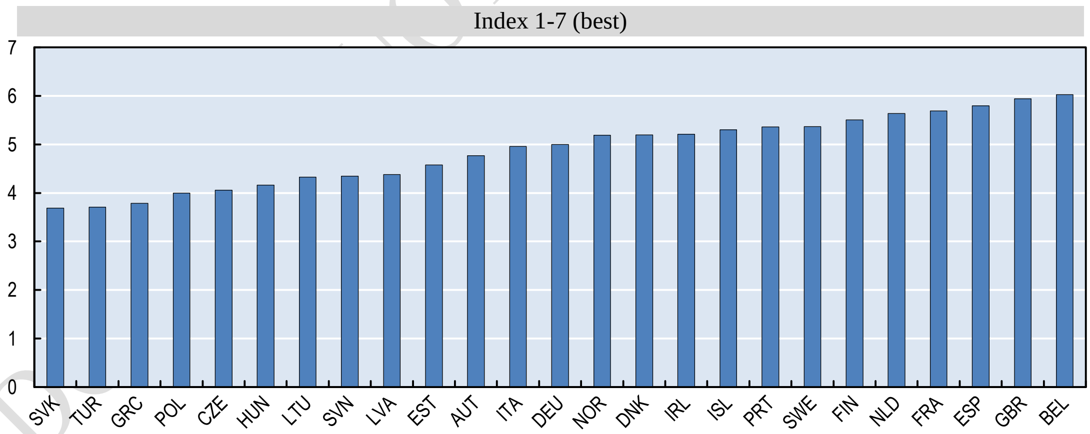
Panel A. High-Performance Work Practices (HPWP) across countries

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)

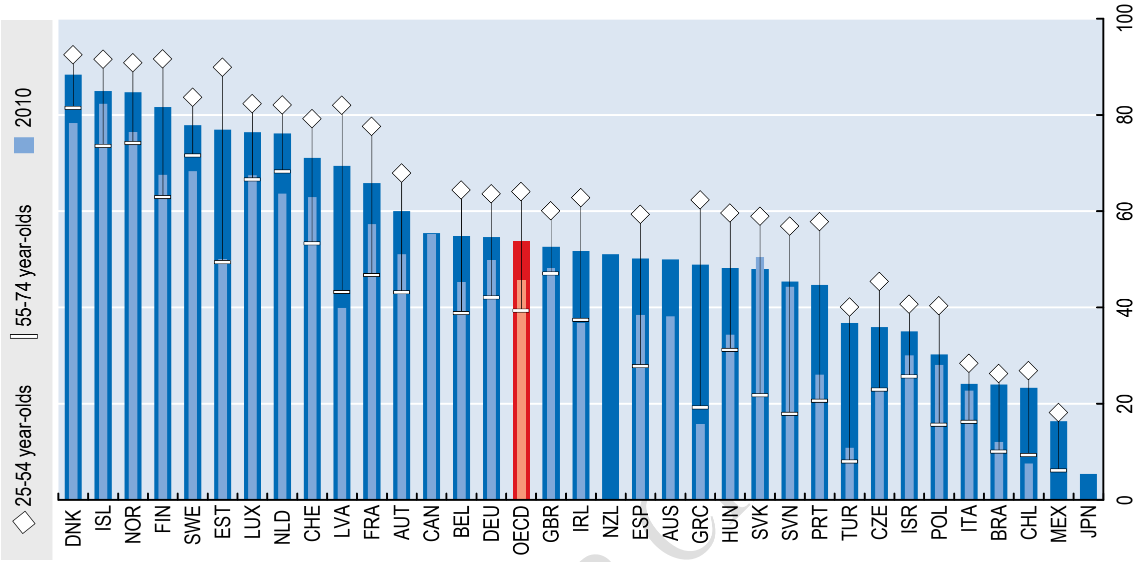
Panel B. The quality of management schools



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.

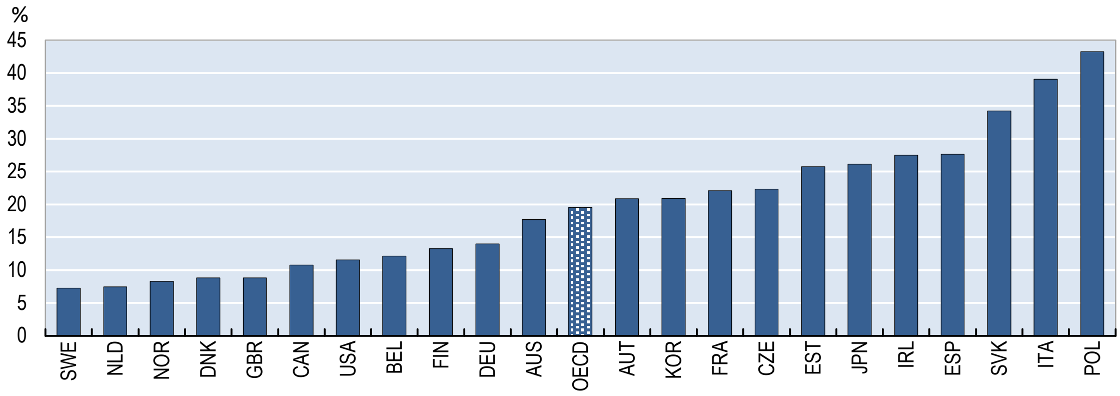
For Mexico, using e-government services includes the following categories: "communicating with the government", "consulting government information", "downloading government forms", "filling out or submitting government forms", "carrying out government procedures" and "participating in government consultations". 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

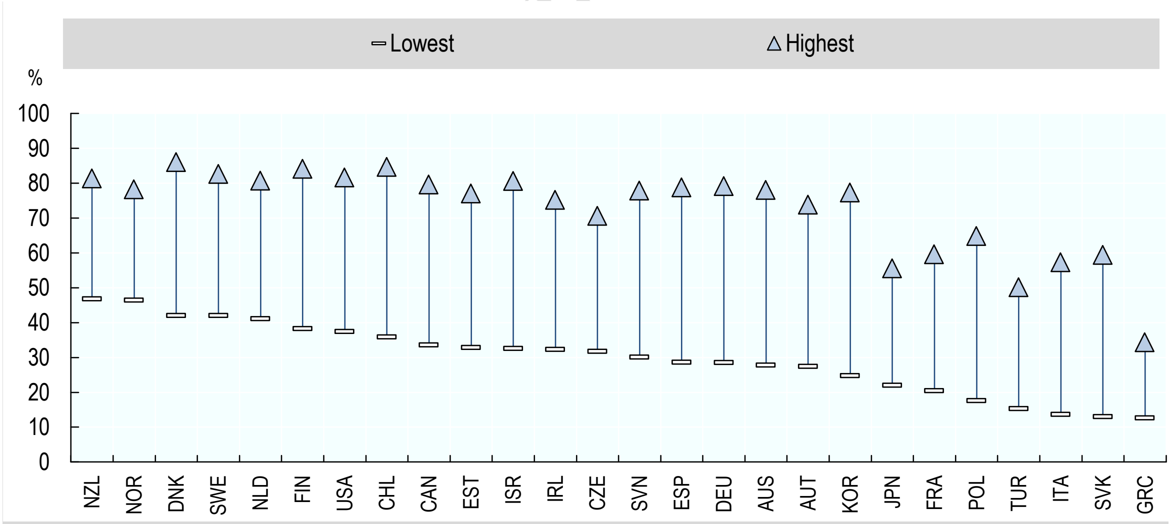
Percentage share of adults (15-65) with insufficient or no ICT experience



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



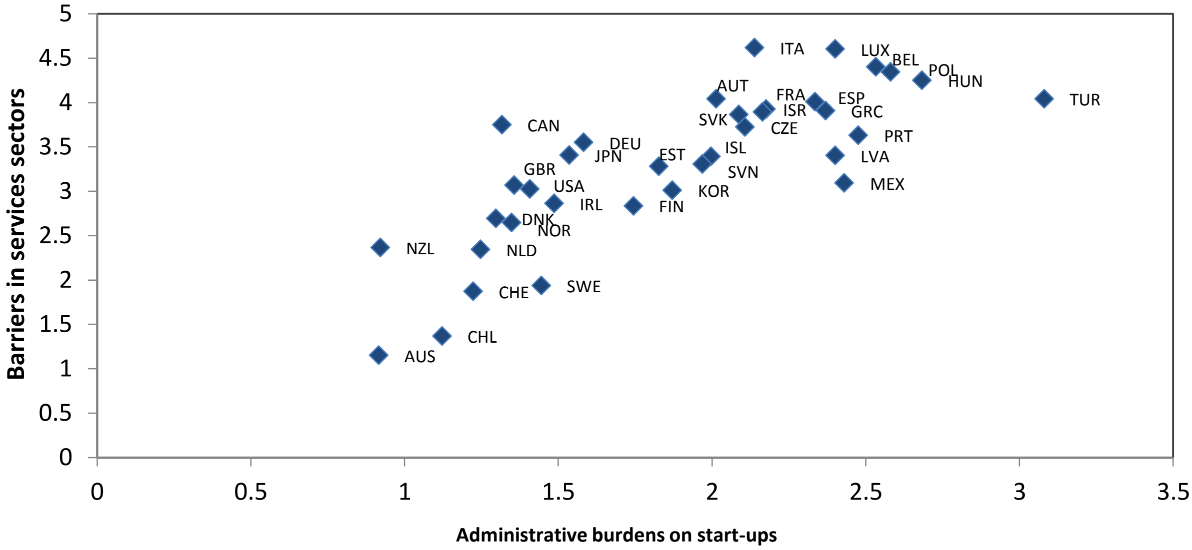
Note: Participation in formal and/or non-formal education refers to participation in the 12 months prior to the survey. Columns showing data broken down by gender are available for consultation on line (see Statlink below. For Chile, Greece, Israel, Lithuania, New Zealand, Singapore, Slovenia and Turkey,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

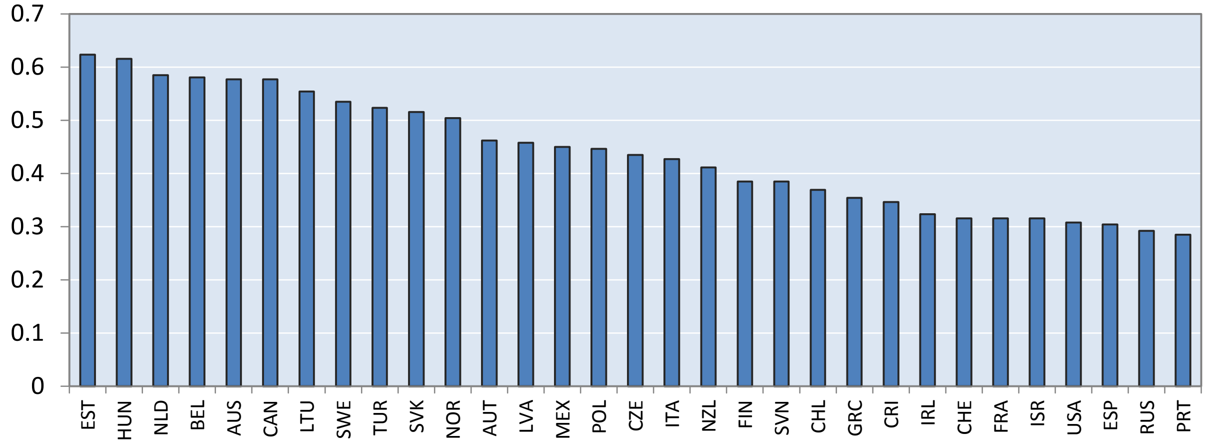
Higher values indicate higher barriers to entry



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

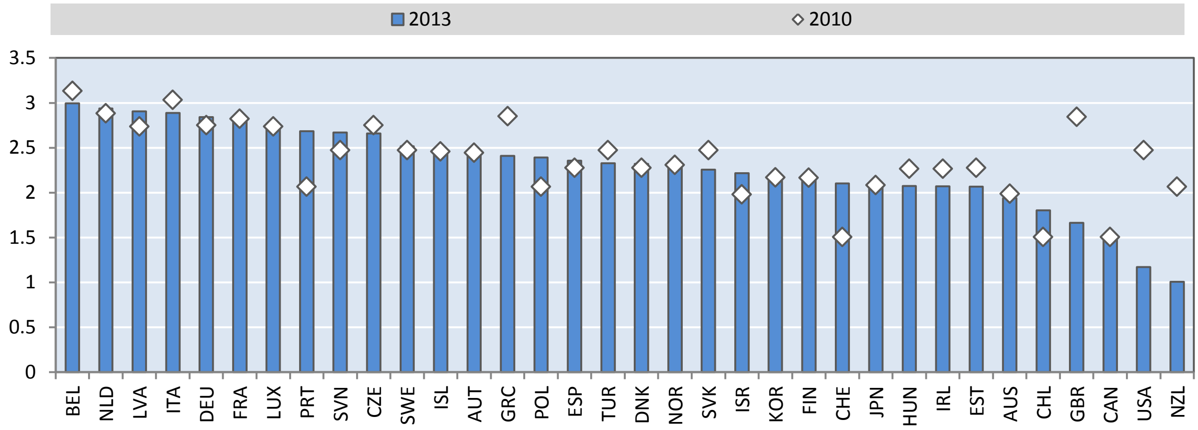


Note: Calculations based on the OECD questionnaire on insolvency regimes.
Source: Adalet McGowan et al. (2017b)

Figure A.7. Labour market settings

Strictness of Employment Protection Legislation, 2010 and 2013

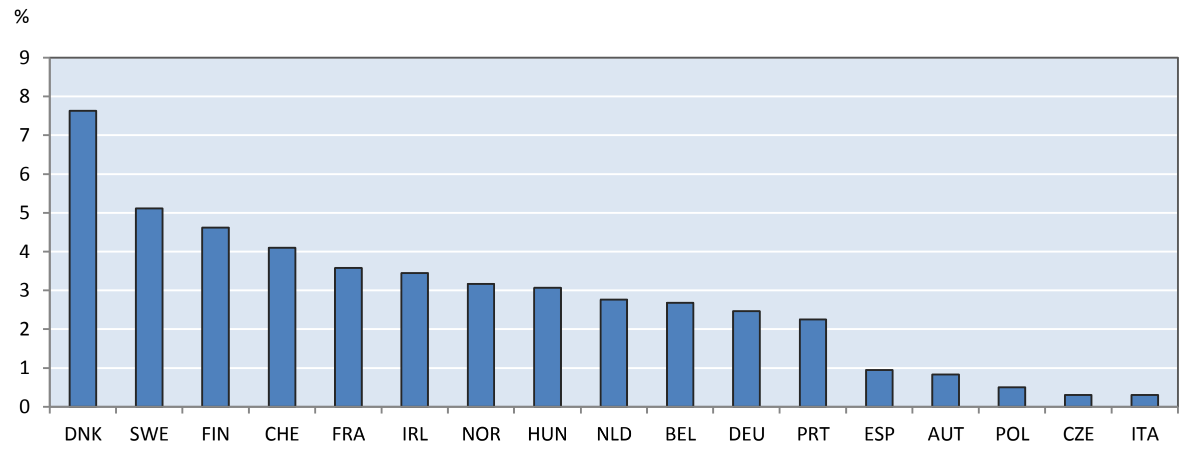
Increasing in restrictions on collective and individual dismissals for workers with regular contracts



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

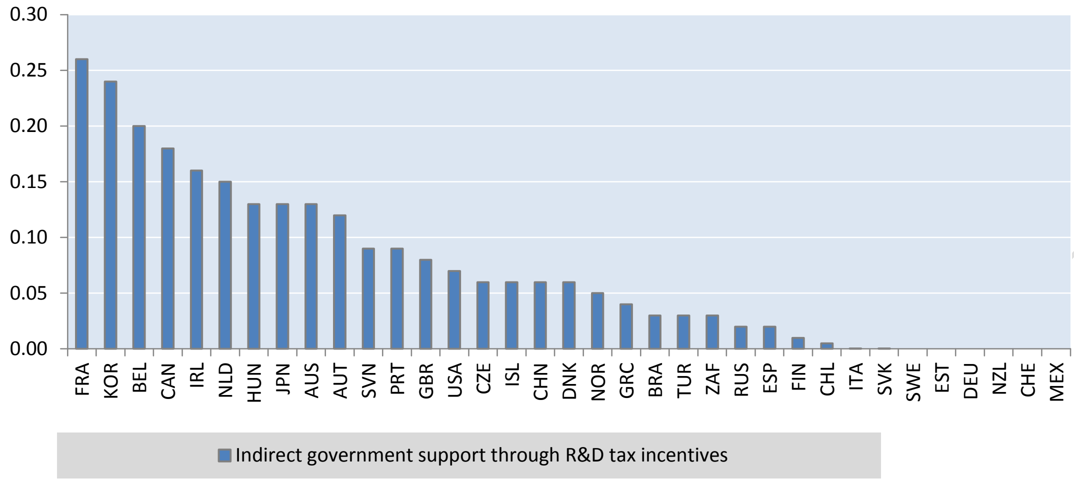
Venture Capital as a percentage of GDP



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

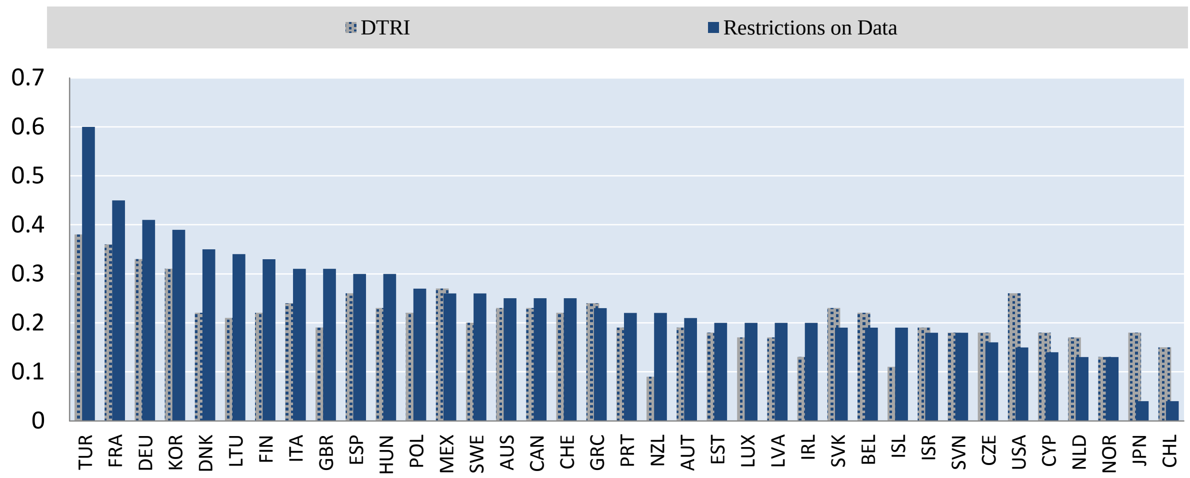
As a percentage of GDP



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 International 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. EPL interacted with job turnover

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

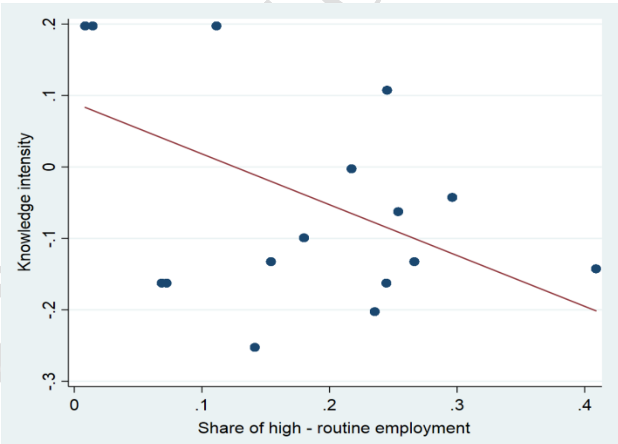
	ERP	CRM	Cloud Computing	Cloud Computing (high)
High-speed internet	0.205***	0.236***	0.161***	0.102**
	(0.0624)	(0.0648)	(0.0543)	(0.0465)
EPL* Job turnover	-0.00197**	-0.00119*	-0.000594	-0.000790*
	(0.000806)	(0.000659)	(0.000562)	(0.000417)
Constant	0.576***	0.503***	0.181***	0.139***
	(0.0927)	(0.0728)	(0.0623)	(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.

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.3. 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-Governent 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 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 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.4. 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.5. 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

1.1. 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)).[31] 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.

31 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).

1.2. 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).