LATVIJAS BANKA
EIROSISTĒMA

ISBN 978-9934-578-72-4

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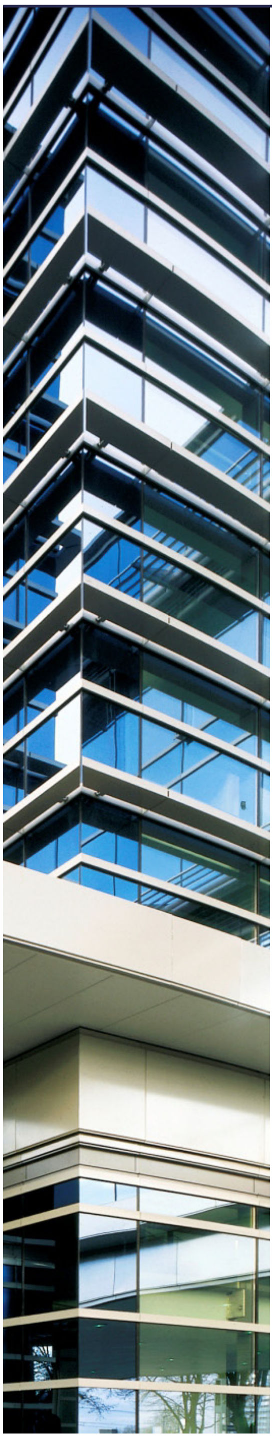

DISCUSSION PAPER
1 / 2025

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Adoption of digital technologies: the case of Latvian firms

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April 8, 2025

Abstract

This study examines the adoption of digital technologies by Latvian firms, focusing on the factors influencing adoption decisions and the impact of these technologies on firm performance. Using firm-level responses to the digitalisation survey, the paper covers four technologies: broadband internet, webpages, web sales, and EDI sales. The results suggest that larger firms, exporters, and those employing ICT specialists along with a higher-skilled workforce, are more inlined to adopt digital technologies. The provision of relevant training programmes for both ICT and non-ICT staff is essential for fostering technology adoption, particularly for more complex systems like web sales. To assess the impact of digitalisation on firm performance, the study employs a difference-in-differences approach, finding that webpage adoption positively affects turnover and employment, particularly in the manufacturing sector. EDI sales also enhance firm performance, boosting turnover and employment. The study emphasises the need for complementary investments in workforce skills, ICT training, and organisational restructuring to fully realise the benefits of digital transformation.

JEL codes: D22, O14, O33, L25, J23, J24, F14

Keywords: Digital technologies, e-commerce, firm performance

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1 Introduction

The widespread expansion and use of information and communication technologies (ICT) have been evient over the last decades across countries and sectors. However, it raises questions why this surge in ICT has been accompanied by stagnation rather than acceleration in productivity growth. This so-called productivity paradox has been pointed out by several authors (see, for instance, Acemoglu et al. (2014); Brynjolfsson (2011); Brynjolfsson and Syverson (2017)), since the expansion of ICT is generally associated with productivity gains.

A commonly cited explanation for this paradox is the growing disparity in productivity performance across firms (Andrews et al. (2015), Gal et al. (2019), Berlingieri et al. (2018)). For instance, ECB (2021) illustrates that aggregate productivity growth is mainly driven by more productive firms operating at the frontier of the economy, whereas less productive firms face difficulties to keep up with their more productive peers. As a next step, the academic discussion has focused on the factors that enable or hinder firms to adopt and implement new technologies, as these factors are found, in general, to explain heterogeneous technology adoption rates and productivity performance at the firm level.

The combination of factors that affect the technology adoption by firms has been extensively studied at the aggregate and firm levels, across several countries. The analysis of technology adoption has been based on aggregate ICT measures or the adoption of specific technologies. The findings of this analysis reveal that the determinants of technology adoption vary across different types of technologies adopted and across firms (DeStefano et al. (2017); Andrews et al. (2018)). Among the factors typically examined in the technology adoption decision are firm characteristics like size, age, the availability of suitable human capital, as well as the firm's organizational structure. Moreover, the regulatory environment, along with the product, labour, and financial structure of the economy in which the firm operates, are also found to affect the propensity to adopt new technologies.

The current paper focuses on the case of Latvia and studies the factors affecting the decision to adopt different types of ICT by Latvian firms. The case of Latvia is an interesting one, as according to OECD (2021) Latvian firms lag behind those of other OECD countries in terms of the adoption of new technologies such as e-commerce, having a webpage and in terms of the use of more sophisticated technologies (such as ERP software, CRM software, RFID technology, cloud computing and big data). Using the results of the Community survey on ICT usage and e-commerce in enterprises that presents data on several types of technologies adopted by individual firms, we start by comparing the performance of Latvian firms in terms of technology adoption rates across firm characteristics.

Since Latvian firms have not significantly benefited from the adopting new technologies, they provide a unique sample that could be used to study the factors behind their sluggish technology adoption rates. Given the rich set of technology indices and firm characteristics available in the new dataset since 2015, to the best of our knowledge, this is the first attempt to empirically study the reasons for the low rates of technology adoption by Latvian firms. It takes into account firm-level characteristics, since firm-level analysis has a significant measurement advantage, as it allows eliminating many biases resulting from aggregation and accounts for firm level heterogeneity (Pantea et al. (2017); Gal et al. (2019)).

Given that the factors impacting the adoption of new technologies differ by the type of technology adopted, there is an attempt to extend the analysis to several technology dimensions. The main types of technology used in this paper are driven by data availability, starting with the existence of a broadband connection for business purposes. As indicated in existing studies, the existence of the broadband internet is a prerequisite for the adoption of more complex technologies (DeStefano et al. (2017); Andrews et al. (2018); Bartelsman et al. (2017)). The use of a website is also considered as a means that makes the firm more visible to its clients. Finally, the engagement of firms in e-commerce activities (e-sales), i.e. web sales or electronic data interchange (EDI) sales, as a more complex form of information technology is also studied.

The main reasons for slow technology adoption in Latvia identified by OECD (2021) are that Latvian firms are small in size with low innovative ability; financially constrained as the access to lending has remained low since the global financial crisis; lack of professionals with managerial and administrative skills who would facilitate the adoption and absorption of new technologies. Complementary to this is the lack of ICT professionals to implement and operate new systems. Since the availability of skills at the firm level is central to the report as a key factor, we incorporate many proxies, including ICT specialists, as well as several training variables available in the study. While the availability of training has been studied mainly from a cross-sectional perspective,[1] this paper also incorporates a time dimension to make any statement more solid.[2] The first question this paper asks is: what are the main determinants of ICT/e-commerce use by Latvia's firms?

Based on the available firm characteristics, our results suggest that the determinants shaping the use and adoption of a new technology, vary depending on the type of the technology studied. In general, larger and exporting firms, exporters, and those employing ICT specialists and highly skilled employees are more likely to have already adopted or to adopt new technologies. Heightened, domestic competition from inside the industry, as well as a larger share of competitor already possessing the technology of study (spillover effects) motivate a firm to engage in the same type of technology to maintain its market share. Age and foreign ownership do not exhibit a stable effect. Finally, offering ICT training to non-ICT specialists seems to matter for a firm to use a wide range of technologies explored in this

[1]See for instance Hollenstein (2004) for Switzerland; Oliveira and Martins (2008) for Portugal.

[2]For studies with a time dimension see Cirillo et al. (2023) for Italy and López-García and Montero (2010) for Spain. However, we can make a distinction between ICT and non-ICT specialists training, which is not addressed in these two studies that rely on aggregate measures of training.

study, with the role of training to ICT specialists playing a complementary role in boosting technology adoption by firms when a firm uses or adopts more complex types of ICT, like web sales.

As a second step, this analysis goes further and tests whether the adoption of ICT/e-commerce technologies affects the performance of Latvia's firms. To measure performance we use three outcome variables of a firm: turnover, employment and productivity. Firm level analysis has the advantages of accounting for firm heterogeneity as described above, but it suffers more from endogeneity issues and misses out spillover effects (DeStefano et al. (2017); Andrews et al. (2018); Syverson (2011)). To overcome the potential endogeneity issues associated with an analysis at the firm level, we employ the propensity score matching technique, where the firms adopting a type of technology are compared to a group of firms with similar characteristics that do not adopt any type of technology. This accounts for the fact that some firms are more inclined to adopt new technologies than others. For instance, larger and more productive firms typically have easier access to financing and are better positioned to attract a more qualified pool of human capital, which makes them more eager to adopt new technologies compared to smaller firms. Finally, our analysis uses lagged explanatory variables to avoid simultaneous feedback effects and to account for the time needed for the adoption of a new technology to yield measurable improvements in productivity and profit gains.

Our analysis shows that the contemporaneous effect of ICT on firm performance depends on the technology variable studied. The use of a webpage affects positively firm turnover and employment, without any effect on productivity. Regarding e-commerce, only the adoption of EDI is found to affect positively a firm's turnover and employment, with no effect on productivity. In turn, web sales do not affect any firm outcome in a statistically significant way. Given the nature of our data, we believe that the productivity effect might take considerably longer to materialise. Also, the insignificant effect of web sales on firm performance might suggest the presence of sunk costs in the short run related to the purchase and the adoption of new ICT and the related complementary investments in organisational and human capital. Smaller firms might find it more difficult to finance these sunk costs and even lack the knowledge to implement the new technologies efficiently. In the short run, they might even face negative returns on profits and productivity. Finally, we extend the analysis to subsequent periods, although this is accompanied by a substantial loss of data and a consequent reduction in sample size. The dynamic analysis yields mixed results, particularly with regard to the impact of EDI adoption.

The results of this paper are policy relevant. First, they suggest that a firm's decision to digitalise depends on the availability of specialised human capital to be hired and operate the new technology adopted. Moreover, a workforce with general skills is also needed to assist the implementation of new technologies, alongside ICT specialists. Second, to reap the full benefits of the digitalisation process in terms of productivity and profits, a firm needs to invest in organisational and human capital. Therefore, education policies aimed at nationwide specialisation in ICT and general-purpose skills aligned with business needs are recommended.

The rest of the paper is structured as follows. Section 2 reviews the main determinants of technology adoption and the channels through which it affects firm outcomes. Section 3 describes the dataset, defines key concepts and provides description of the main variables used. Section 4 outlines the estimation methods used. The main results are discussed in Section 5 and Section 6. Section 7 concludes.

2 Empirical evidence on the use and impact of ICT

The current section focuses on the discussion of the main studies in the literature regarding the factors that determine the adoption of new ICT. Then the effect of these technologies on firm outcomes such as productivity, profits and labour demand, with a particular focus on the transmission channels.

2.1 Determinants of technology adoption

Several explanations have been put under the microscope regarding the factors affecting the adoption and diffusion of new ICT by firms. The most prevalent explanation is that, despite the availability of ICT, various factors hinder less productive firms from adopting these technologies compared to their more productive counterparts across sectors and countries. Initially, a firm's decision to adopt a new technology depends on firm characteristics. Firm size is identified as a main factor as larger firms are more likely to adopt certain technologies compared to smaller ones (DeStefano et al. (2017); OECD (2015); Gal (2013)). Larger firms might have easier access to finance owing to their ability to provide stronger guarantees (Haller and Traistaru-Siedschlag (2007)), or find it easier to attract the relevant skill pool to support the implementation of new technologies. They might also possess a great stock of knowledge and have an advantage in the adoption of new technologies. On the other hand, adjustment costs to production processes might be higher in larger firms compared to smaller ones. Larger firms, typically associated with higher productivity, are more inclined to invest in new technologies as they already possess the know-how and a large stock of intangible assets (Gal (2013)).

The effect of a firm's age is ambiguous. Age matters as the cost of adopting new technologies and changing production processes might be considerable, whereas the benefits from the accumulation of new knowledge might outweigh the cost of adopting new technologies (DeStefano et al. (2017)).

The available human capital and skill pool to complement and support the implementation of the new adopted technologies is also a considerable factor (DeStefano et al. (2017); Gal (2013); Andrews et al. (2018); Machin and van Reenen (1998); Autor et al. (2003); Bartel et al. (2007)). Firms with a stock of highly skilled workers (with enhanced capability to use ICT) are more likely to adopt a new technology compared to firms with less skilled workers (Bresnahan et al. (2002)). This is because better educated workers are typically more proficient at mastering new technologies and exhibit greater flexibility in adapting to changing job assignments. With the adoption of a new technology that changes the organisational structure of a firm, more educated highly skilled workers are better equipped to implement the new technology more efficiently (Bayo-Moriones and Lera-López (2007); Haller and Traistaru-Siedschlag (2007)). Therefore, it is not only the presence of ICT specialists capable of implementing the new technology, but also the availability of a workforce with generic ICT skills and continuous training to support the use of such technologies in a firm. Firms with a higher stock of intangible assets such as worker and managerial skills that complement ICT increase the propensity of a firm to adopt such technologies (Bloom et al. (2012); Bloom et al. (2012); Andrews et al. (2018)).

A firm's organisational structure also plays a role. A firm's position within the organisation, and whether a firm is a plant or headquarters might also play a role (DeStefano et al. (2017)). Hollenstein (2004) argues that teamwork and horizontal structure are organisational characteristics that encourage ICT adoption. Whether a firm is foreign-owned or not is important an important factor as foreign-owned companies can easily adopt new technologies already adopted by their foreign owners (Haller and Traistaru-Siedschlag (2007)).

Moreover, the policy and regulatory environment, as well as product, labour, and financial market characteristics could affect a firm's incentive to invest in digital technologies. The market structure of the sector in which a firm operates matters, as a competitive environment might incentivise firms to invest in complex ICT to maintain their market share (Conway et al. (2005); Andrews et al. (2018); Aghion and Griffith (2005); Perla et al. (2021); Bloom et al. (2015); Bayo-Moriones and Lera-López (2007)). Apart from the domestic competitive pressures, a firm's status as an exporter also matters, as it reflects the foreign competition faced by firms engaging in foreign trade. An additional factor for technology adoption is spillovers. If a firm belongs to a network, an industry or region where other firms are already adopters, it will tend to adopt similar technologies (Hollenstein (2004); Gal et al. (2019); Andrews et al. (2018)).

Access to finance and the existence of risk capital enables firms, especially young entrants, to take up new technologies and stay in the market, as it helps to cover the cost of investing in such technologies (Hall and Lerner (2009); Gorodnichenko and Schnitzer (2013)). Bartik et al. (2020) shows that US small firms are financially more fragile with not enough cash in hand to cover current expenses during the COVID-19 pandemic, with increased willingness to participate in state-funded assistance programmes.

Flexible labour market policies enable firms to adjust their labour input more easily to cope with the costs of a new investment, or to employ new employees with the required skills to support the new digital investment (Bartelsman et al. (2013); Bartelsman et al. (2017)). In this context, offering ICT training could help firms align the knowledge of their existing workforce with the new technological investment needs (Hollenstein (2004)). Policies that enable access to stable and fast broadband internet are found to be a prerequisite for access to more complex digital technologies (DeStefano et al. (2016); Andrews et al. (2018); Bartelsman et al. (2017)).

2.2 The effects of technology adoption on firm performance: a review of the channels

The second question this study addresses is the effect that ICT has on various firm outcomes, including productivity, profits, and labour demand. The sign and size of the effects are found to be ambiguous in most cases.

At a macro level, the adoption of digital technologies improves productivity via an increase in total factor productivity in ICT-related sectors and via spillover effects to sectors adopting ICT in the rest of the economy. As technology advances, the cost of capital decreases and the capital-labour ratio increases (capital deepening).

A number of studies have estimated the impact of ICT and digitalisation on firm-level productivity and seem to converge towards a net positive effect of ICT investment on value added (Gal et al. (2019) for 20 countries; Hall et al. (2013) for Italy; Cette et al. (2022) for France; Falk and Hagsten (2015) for 14 countries; Monteiro et al. (2021) for Portugal; Ballestar et al. (2020) for Spain). ICT investment is translated into productivity gains, as it enables "organizational" investments, mainly business processes and new work practices which, in turn, lead to cost reductions and improved output and, hence, productivity gains (Hall et al. (2013) for Italian firms). Digital technologies boost worker skills and labour productivity complementary to the implementation of new technologies (Gal et al. (2019)). Digital technologies allow firms to grow quickly and achieve scale without mass (Haskel and Westlake (2017)). They also increase competitiveness and market size through the potential of e-commerce as discussed in Section 2.3. As a result, ICT investment promotes output and profits (Gal et al. (2019) for 20 countries; Dhyne et al. (2018) for Belgium; DeStefano et al. (2018) for the United Kingdom; Abidi et al. (2023) for 13 countries; Monteiro et al. (2021) for Portugal).

Other studies find more limited direct effects of these technologies on productivity at a micro level (Acemoglu et al. (2014) for the US; Bartelsman et al. (2017); DeStefano et al. (2018) for the United Kingdom). Acemoglu et al. (2014) demonstrate that whenever present these productivity effects are mainly driven by a larger decline in employment compared to output. Bartelsman et al. (2017) find no effect of the use of broadband internet on average firm productivity, but a positive effect on aggregate industry productivity, indicating that the innovative process is driven by larger and more productive firms in the industry. DeStefano et al. (2018) conduct a study of UK firms accounting for the endogeneity between technology adoption and firm performance. They find a positive impact of ADSL internet connection on output and employment, but no effect on labour productivity.

ICT are found to promote innovation, including product innovation (Bartelsman et al. (2017); Van Leeuwen (2008))), as they reduce production costs, raise output and improve productivity (Bartelsman et al. (2017) for 14 countries; Polder et al. (2010) for Dutch firms). Moreover, ICT can be seen as a separate input in the organisational innovation, which is complementary to ICT investment like new management techniques, business models, work processes, and human resource practices (Brynjolfsson et al. (2002)). Polder et al. (2010) indicate that ICT is a direct input "for producing new services (like internet banking), new ways of doing business (B2B), new ways of producing goods and services (integrated management) or new ways of marketing (e.g. electronic cataloguing)".

Finally, ICT promotes technical efficiency by reducing the price of inputs or increasing their quality allowing firms to produce more with the same amount of inputs, moving closer to the production possibility frontier (Castiglione (2012) for Italy).

Regarding labour market effects, the short-run effect might be negative as new technologies may replace workers in jobs with more automative tasks (job displacement effect), while increasing the demand for highly skilled workers needed to adopt the new skills to complement the implementation of the new IT investment (job polarisation). In the long run, there is a positive spillover effect, as the new technologies are used across the economy and this might create demand for new occupations (compositional effect). This crucially depends on the efficiency of the job matching process and the balance between the supply and demand for new skills. Empirical evidence is mixed. Some studies identify a negative short-run effect (Ballestar et al. (2020) on employment for Spain; Cette et al. (2022) on labour share for France), whereas in other studies the positive effect is found to dominate (DeStefano et al. (2018) for the United Kingdom; Abidi et al. (2023) for 13 countries; Arntz et al. (2022) for Germany). Finally, a neutral effect is also found in some papers (Biagi and Falk (2017); Pantea et al. (2017)).

The magnitude of the effect of ICT adoption on firm performance (productivity, employment, etc.) is higher when there are complementarities with other types of investments. These include investments in organisational capital and managerial skills (Andrews et al. (2018); Gal et al. (2019); Aral et al. (2012); Bresnahan et al. (2002); Bloom et al. (2012); Bloom et al. (2012)); human capital and ICT-related skills (Bugamelli and Pagano (2004); Andrews et al. (2018); Gal et al. (2019); Ballestar et al. (2020); Cammeraat et al. (2021);

ECB (2021)); different technologies (Aral and Weill (2007); Bartelsman et al. (2017)) and policies to promote competition and efficient resource reallocation (Conway et al. (2005); Bartelsman et al. (2013); Bailin Rivares et al. (2019); Aghion et al. (2009)).

2.3 The definition and the role of e-commerce

E-commerce (e-sales) is defined as the orders of goods and services that firms receive electronically (over computer networks) without any use of telephone, facsimile or manually typed e-mails. E-commerce can take place in the form of web sales via a firm's websites or web applications. It can also take the form of electronic data interchange (EDI) sales. EDI sales are the computer-to-computer exchange of standard electronic data or documents between business partners over a secure, standardised connection without human intervention.

Without an EDI process in place, a buyer (company) prepares its purchase order of a product or service on paper and then sends it to the supplier (company) of the product or service either via scan, fax or postal/electronic mail .[3] With an EDI process in place, the intermediate step of the need to use scan, fax or postal/electronic mail to deliver the purchase and the invoice documents between the two business partners is not needed, as it is done via EDI-type of messages between the EDI computer systems available to the buyer and the supplier. This makes the process faster and more automated, at reduced costs and with less errors, without the need of a person to perform the intermediate step. An example of an EDI proccess is as follows: when a company's (purchaser) inventory stock reaches a pre-specified level, an automated message is generated from the company's EDI system and sent to the supplier's EDI system. The supplier's EDI system will send an EDI message to the purchaser's EDI system aknowledging the receipt of the inventory order. Once the products are packed and ready for shipment, an EDI message containing the payment invoice for the delivery the requested products is sent from the supplier's EDI system to the buyer's EDI system.

Apart from being digitilised, EDI processes differ from web sales in that they are performed among larger firms, the business relationships with the customers are more formal and on a longer-term basis. In the case of web sales, a supplier's customers are mostly smaller firms or individual consumers that make their purchases manually over the suppliers website or application (for instance on-line e-shop of a textile company). Customers relationships are informal and short-lived.

Like any ICT, e-commerce provides additional channels in for firms to interact with their customers and enter new markets, reduces sales costs, facilitates information gathering, consolidates supply and demand, decreases the need for intermediaries and a physical presence. It has been established that e-commerce has a positive effect on international trade (Terzi

[3]See https://www.edibasics.com/what-is-edi/ and https://arc.cdata.com/resources/edi/

(2011); Morgan-Thomas (2009); Yue and Li (2019); Burinskiene (2012)), firm performance (Sanders (2008); Quirós Romero and Rodríguez Rodríguez (2010); Polder et al. (2010) for Dutch firms; Ballestar et al. (2020) for Spain), productivity (Xia and Zhang (2010) for the US; Liu et al. (2013) for Taiwan; Bertschek et al. (2006) for Germany; Ortega, Leonardo and Cathles, Alison and Grazzi, Matteo (2017) for Chile; Falk and Hagsten (2015) for 14 countries; Ballestar et al. (2020) for Spain).

3 Firm level data

3.1 Survey on ICT usage and e-commerce in Latvia's enterprises: representativeness

The data on ICT adoption originates from the annual survey on ICT usage and e-commerce in enterprises, an initiative conducted by statistical agencies in the European Union.[4] This initiative aims to gather comprehensive information on how businesses utilise information and communication technologies and engage in e-commerce. The data collection is carried out through an online questionnaire completed by a firm's IT specialist or owner. The survey targets enterprises with at least 10 employees or self-employed persons.

The first survey in Latvia was conducted in 2016 (covering data from 2015). As of this writing, results from seven surveys are available, with the latest conducted in 2022 for the year 2021. Typically, firms participate in the survey for a limited number of years, with only 196 firms in Latvia having participated in all seven years. A notable issue with the survey is the lack of consistency in the questions asked each year. However, questions regarding the use of broadband internet, a website, and e-commerce have been consistently included in all previous surveys, guiding our selection of questions for this study. Conversely, the adoption of ICT innovations such as big data, robots, and 3D printing has been assessed in only two surveys.

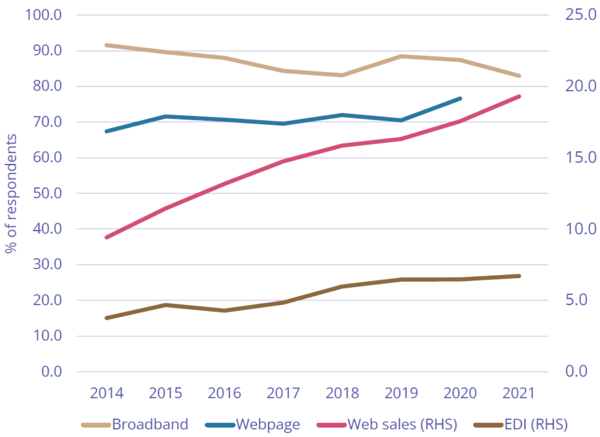
Each year, approximately 2500–3000 firms, representing around 2.5% of all firms, participate in the survey. These firms account for approximately 30%–40% of total turnover, indicating that the surveyed firms are generally large. The majority of surveyed firms are located in the manufacturing and trade sectors. In terms of turnover, the surveyed firms account for approximately 60% of the manufacturing and ICT sectors, 70% of the electricity/water sector, 40% of the accommodation and food, and transportation sectors. In the professional services sector, the surveyed firms represent only 10% of the total turnover, as this sector is predominantly composed of a large number of small firms.

Figure 1 shows the evolution of the four type of technologies used in the present study.

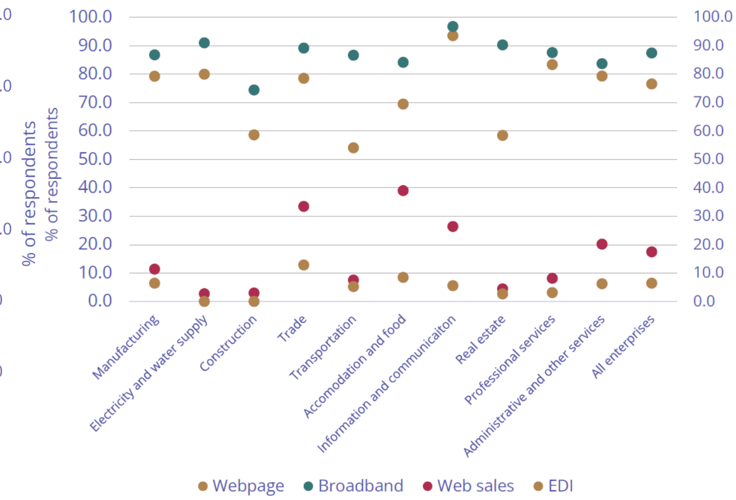
[4] See details https://ec.europa.eu/eurostat/cache/metadata/en/isoc_e_esms.htm

Figure 1: The use of ICT/e-commerce in Latvia's firms

(a) The share of firms which use ICT



(b) The share of firms which use ICT by sector, 2021



Source: Statistics Latvia, authors' calculations.

Broadband use is predominant with around 90% of responding firms already utilising it, followed by webpage by 70% of the firms. The share of firms engaging in web sales has doubled over time, whereas the evolution of EDI sales has remained flat since the launch of the survey. These patterns persist in the sectoral analysis, and it is worth noting the engagement of certain services sectors in web sales such as trade, accommodation and food, as well as information and communication services (around 30% of the responding firms in 2020).

Regarding e-sales, web sales dominate. The percentage of enterprises engaging in web sales is the highest in small enterprises (see Figure 2, left sub-figure). In turn, the percentage of firms using EDI is highest among larger firms. Many small firms engage in web sales, however, the turnover generated by them remained small even in 2021, reaching about 5% of total turnover (see Figure 2, right sub-figure). In the case of larger enterprises, the turnover from e-sales is the largest around 7% for both web sales and EDI.

In 2021, almost all firms in the services sectors (such as electricity and water, construction, accommodation and food services, administration services, information and communication service) engaged in web sales, whereas this share reached 70.4% in ,anufacturing (see Figure 3, left sub-figure). Firms using EDI sales are mostly found in the transportation (53%), electricity (50%), manufacturing (43.5%), and water (41%) sectors. Accommodation and food services enjoy the largest turnover originating from web sales (16%), followed by administrative and professional services (almost 10%) (see Figure 3, right sub-figure).[5] In

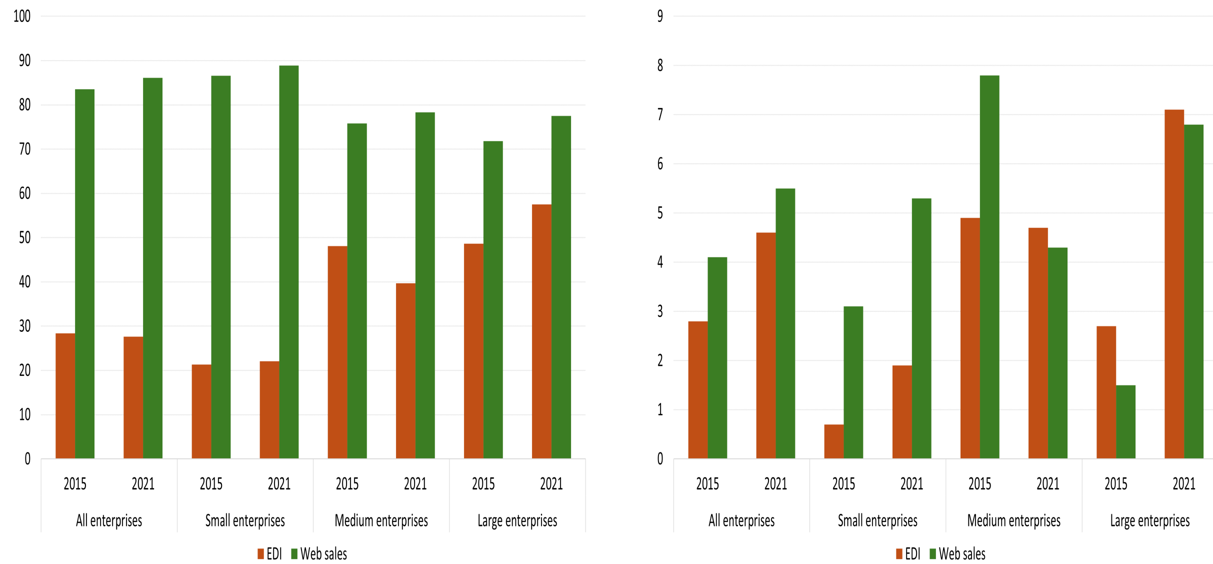
[5]Turnover from web sales is 8.4% for information and communication services, according to the 2023 survey.

manufacturing, the turnover generated by web sales and EDI is fairly balanced (4.8% vs 6.5%). Finally, the turnover from EDI sales is highest in information and communication services, as well as in trade services (about 5.5%, in both sectors).

Figure 2: Web sales vs EDI sales in Latvia by firm size

(a) Web sales and EDI sales by class size, % of firms with e-sales

(b) Web sales and EDI sales by class size, % of total turnover of firms with e-sales



Source: Statistics Latvia, authors' calculations.
Notes: All enterprises = more than 10 employees, small enterprises = between 10 and 49 employees, medium enterprises = between 50 and 249 employees, large enterprises = more than 250 employees.

3.2 Firm level data

To analyse the impact of ICT adoption, we match several anonymised firm-level datasets provided by the State Revenue Service (SRS) and Central Statistical Bureau (CSB) of Latvia with the above described ICT survey.

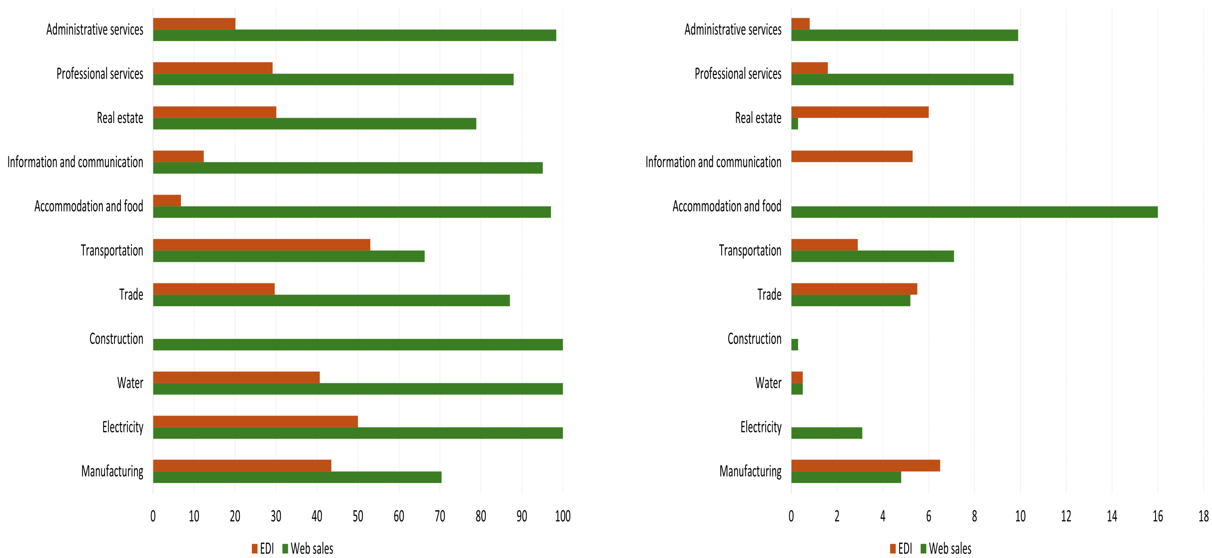
Financial statement data is sourced from the firm's comprehensive indicators database. This database encompasses Latvian firms' balance sheets, profit and loss statements, turnover, number of employees, employee compensation, and value added. Additionally, it includes sectoral information according to the two-digit NACE 2 classification. The number of firms represented in the dataset ranges from 61159 in 2006 to 105741 in 2021.

Data on foreign ownership of firms is derived from the firms' foreign assets and liabilities dataset of Latvijas Banka, which enables the identification of the foreign capital share in companies. Information regarding export activities is sourced from the Goods Trade database of the CSB, which includes data on merchandise flows. Lastly, employee salary information is

Figure 3: Web sales vs EDI sales in Latvia by sector

(a) Web sales and EDI sales by sector, % of firms that have adopted e-sales

(b) Web sales and EDI sales by sector, % of total turnover of firms that have adopted e-sales



Source: Statistics Latvia, authors' calculations. Data are for 2021.
Notes: Figure 3(b) presents data for the electricity and water sectors from the 2023 survey.

obtained from the employer-employee dataset (SRS). It is an administrative dataset covering all legal employees in Latvia.

4 Methodology

To understand the drivers of the decision of firms to adopt ICT, we estimate the following probit regression:

$$Y_{i,t} = \beta_0 + \beta_1 X_{i,t-1} + \alpha_t + \alpha_s + u_{i,t} \tag{1}$$

where $Y_{i,t}$ is a dummy variable that equals 1, if a firm utilises an ICT in time t (and 0 otherwise). Vector $X_{i,t-1}$ represents lagged firm-level characteristics and skill-related variables. We account for several firm characteristics, including the firm's age, number of employees (a proxy for firm size), exporting status (a dummy variable that equals 1 if the firm is an exporter), foreign ownership (a dummy variable that equals 1 if the firm is foreign-owned). To capture potential spillover effects, we consider the proportion of firms within each sector and year that have already adopted a specific type of ICT. This proportion is calculated as the percentage of firms participating in the ICT survey that report adopting each of the four technologies analysed in this study. Furthermore, we incorporate a competitor dummy variable that equals 1 if the number of firms within a given sector and year exceeds 10.

Since this study focuses on employees' ICT-related skills, we include several skill-specific variables. These include a dummy variable that equals to 1 if a firm employs ICT specialists in period $t-1$, a dummy variable indicating whether a firm experiences difficulties in filling ICT vacancies, and a dummy variable reflecting whether the firm provides ICT training for its employees in period $t-1$. Finally, we account for the share of firm employees whose salaries exceed the sector median-a variable that serves as a proxy for the general skill level available at the firm in period $t-1$.

Lastly, α_t and α_s denote time and sector fixed effects, respectively.

We also estimate equation 1 for the probability *to adopt* the technology (rather than just *having* it), i.e. $Y_{i,t}$ is a dummy variable that equals 1, if a firm that previously did not use ICT or an e-commerce technology starts using it from year t.

Next, we employ a difference-in-difference estimation to gauge the impact of ICT adoption on a firm's turnover, the number of employees, and labour productivity (calculated as the ratio between the value added and the number of employees). We examine the impact in the same period when the technology is introduced as it is based on a relatively large number of observations. However, we also extend our analysis to the next two periods at the cost of losing many observations, due to the lack of firms that participate in the survey for several years in a row. The specification of the difference-in-difference equation which we estimate is as follows:

$$\Delta Y_{i,t+h} = \beta_0 + \beta_{1,h} ICT_{i,t} + \beta_{2,h} X_{i,t-1} + \alpha_t + \alpha_s + \epsilon_{i,t} \tag{2}$$

where $\Delta Y_{i,t+h}$ is a change in one of the outcome variables (turnover, size, productivity), h=0,..,2. $ICT_{i,t}$ is a treatment variable which equals one, if a firm adopts one of the ICT, $X_{i,t-1}$ is vector of the above described lagged firm characteristics, α_t and α_s denote time and sector dummies, respectively. The horizon-varying $\beta_{1,h}$ vector is the parameter of interest, as it traces the effect of ICT adoption on firm characteristics in year h following the onset of ICT adoption.

To estimate the immediate impact of ICT adoption using equation (2), we use two groups of firms: a) firms that did not use an ICT in year $t-1$ and started using it in year t (treated firms) and b) firms that did not use an ICT in both years (control firms). However, we admit, that a simple use of treated and control firms is controversial, as firms adopting an ICT could be systematically different from non-adopters along a number of dimensions (as is also shown by the results of equation 1). Hence, we employ a non-experimental matching technique based on a single index that measures the probability of a firm to adopt the ICT conditional upon initial characteristics of a firm (see Rosenbaum and Rubin 1983). To identify this probability, we use the results of the above described probit model.[6] We calculate the

[6]Here we refer to the variant of equation 1 estimation where the dependent variable is the dummy variable

estimated ICT adoption probability (propensity score) for each treated and control firm in our sample and apply the matching approach using the the 5 nearest neighbour method.[7] Matching is conducted among firms within the same two-digit NACE industry.

5 Determinants of technology use and adoption

This section discusses the factors influencing the use and adoption of different ICT among Latvian firms, as revealed by the probit regression results in Table 1. The analysis covers four ICT: broadband, webpage, web sales, and EDI sales. The following factors are identified as key determinants, with their specific impact varying by the type of technology.

Firm size and age

Firm size is a consistent and significant determinant across all technologies. The probability of technology use and adoption increases with firm size. This is evident for both the use and adoption of broadband internet (Table 1, columns 1–2) and EDI sales (Table 1, columns 7–8), as well as for the use of webpages (Table 1, column 3), and web sales (Table 1, column 5). This finding is consistent with the empirical literature, which indicates that larger firms are more likely to engage in technology adoption due to their greater access to financial resources, their ability to attract skilled workers, and their capacity to effectively implement new technologies (DeStefano et al. (2017); Gal (2013); Haller and Traistaru-Siedschlag (2007)).

In contrast, firm age does not exhibit a consistent effect across all technologies. Older firms tend to use broadband and webpages more readily (Table 1, columns 1 and 3), while the age of the firm does not significantly impact the likelihood of using and adopting more complex technologies like web sales and EDI (Table 1, columns 5–8). The negative, albeit insignificant, coefficient for web sales suggests that younger firms may be more open to adopting newer, more sophisticated technologies, possibly due to their greater flexibility and fewer organisational constraints.

Foreign ownership

Foreign ownership has a mixed effect on technology adoption. Although foreign companies are more likely to use broadband (Table 1, column 1) and websites (Table 1, column 3), the effect is less clear for web sales and EDI sales. The presence of foreign ownership often facilitates the adoption of new technologies due to an access to global knowledge networks and external financial resources. However, the impact of foreign ownership is less consistent across more complex technologies, suggesting that local conditions and sector-specific factors might play a more substantial role in the adoption of e-sales.

equal to one if a firm previously did not use ICT and started using it in year t.

[7] We match ICT adopters to five firms with closest propensity score.

Table 1: Probabilities of adopting ICT

	(1) Broadband use	(2) Broadband entry	(3) Webpage use	(4) Webpage entry	(5) Web sales use	(6) Web sales entry	(7) EDI use	(8) EDI entry
Age	0.013***	0.015***	0.009***	-0.005	-0.002	-0.001	0.005*	0.001
Log (employment)	0.182***	0.157***	0.301***	0.053	0.069***	0.023	0.131***	0.070**
Foreign ownership dummy	0.234***	0.223*	0.093*	0.066	-0.040	-0.099	0.089*	0.074
Exporting dummy	0.136***	0.091	0.352***	0.317***	0.238***	0.178***	0.184***	0.148**
ICT employment dummy	0.135**	-0.328**	0.230***	0.236*	0.179***	0.122*	0.157***	0.184**
ICT vacancy filling difficulty	-0.163**	-0.084	-0.143**	-0.347***	0.004	-0.016	-0.002	0.034
Earning above industry median	0.100*	-0.155	0.657***	0.466***	0.346***	0.075	0.355***	0.299***
Competitors dummy	-0.369**	-0.195	0.144	-0.010	0.513***	0.250	0.377**	0.144
ICT adoption share	0.018***	0.003	0.030***	0.003	0.033***	0.018***	0.039***	0.017***
ICT training for ICT employees	0.091	0.333	0.044	0.115	0.114*	0.177*	0.049	0.010
ICT training for other employees	0.202***	0.157	0.249***	0.019	0.112**	0.105	0.056	0.041
Constant	-0.676**	-0.753	-2.531***	-0.898**	-2.430	-2.449***	-2.458***	-2.836***
N	10490	1134	10490	2658	10526	8864	10528	9905

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, Year and sector dummies are included. All variables are lagged.

Export status

Firms engaging in exporting activities are more likely to use or adopt ICT, particularly webpages and e-sales (Table 1, columns 3–8). This is likely driven by the need to improve visibility in foreign markets and maintain competitiveness in a globalised economy. Exporting companies face external pressure to modernise their digital infrastructure, making them more inclined to adopt technologies that improve market accessibility.

Human capital and ICT specialists

The availability of skilled human capital is an important determinant of technology adoption. Firms employing ICT specialists are more likely to use all four types of ICT studied (Table 1), with the probability of technology use increasing as firms employ more specialised skills. The role of ICT specialists is crucial for ICT, where ongoing technical support and expertise are essential for successful implementation. The ease of filling ICT-related vacancies positively affects the likelihood of a firm to use or adopt a webpage (Table 1, columns 3–4) and use broadband internet (Table 1, column 1).

Furthermore, the general skill level of the workforce, proxied by the share of employees earning above the industry median, positively impacts both the use and adoption of webpages (Table 1, columns 3–4) and EDI sales (Table 1, columns 7–8) as well as the use of web sales (Table 1, column 5). Higher wages indicate a more skilled workforce that is better equipped to integrate new technologies into the firm's operations. The availability of skilled workers facilitates the smooth implementation of ICT solutions and enhances the firm's capability to adapt to technological advancements.

Training and skill development

The availability of training for both ICT and non-ICT specialists appears important for some technologies, confirming the results from some of the previous literature (Bartelsman et al. (2013); Bartelsman et al. (2017); Hollenstein (2004)). Firms that provide training in digital skills to non-ICT employees, are more likely to use broadband, webpages, and web sales technologies (Table 1, columns 1, 3, 5). This is particularly important for technologies like broadband and webpages, where a broader workforce is involved in leveraging digital tools to improve business processes. At the same time, ICT specialists are likely to already possess the required skills.

For more complex technologies such as web sales, the training of ICT specialists becomes equally important (Table 1, columns 5–6), as the support of web sales requires continuous updates and specialised knowledge to manage implementation and maintenance. The positive coefficient for ICT training among non-ICT specialists in the case of web sales adoption further underscores the need for a dual approach, where both specialists and general employees are equipped with the necessary skills to support technology adoption. In this context, the insignificant effect on EDI adoption is surprising. Successfully maintaining and implementing a complex system like EDI probably requires well-prepared employees who already possess the necessary skills.

Competitive pressures and spillover effects

Firms are more likely to adopt technologies if their competitors have already done so (i.e. the proportion of firms in the same industry that have already adopted the technology is high). This is true for the use of broadband and webpages (Table 1, columns 1 and 3), as well as for both the use and the introduction of e-sales (Table 1, columns 5–8). Spillover effects from industry peers create a pressure to keep up with technological advancements, especially in highly competitive industries where technological adoption can play a key role in sustaining market share. This finding aligns with the existing literature (Hollenstein (2004); Gal et al. (2019); Andrews et al. (2018)).

Finally, encountering a larger number of competitors in the industry stimulates the use of e-commerce (Table 1, columns 5 and 7). Firms operating in highly competitive domestic markets are more inclined to adopt advanced technologies to sustain their market position (Conway et al. (2005); Andrews et al. (2018); Aghion and Griffith (2005); Perla et al. (2021); Bloom et al. (2015); Bayo-Moriones and Lera-López (2007)).

In summary, the factors influencing ICT adoption among Latvian firms vary depending on the technology in question. Larger firms, exporters, those with skilled human capital, and those facing competitive pressures are more likely to adopt new technologies. Moreover, the presence of ICT specialists and the provision of relevant training programmes for both ICT and non-ICT staff are essential for fostering technology adoption, particularly for more complex systems like web sales. Spillover effects from competitors within the industry further enhance the likelihood of adoption, emphasising the importance of industry-wide digitalisation trends.

6 The impact of ICT adoption on firm performance

6.1 Contemporaneous effects of ICT adoption

Having identified the key factors influencing the use and adoption of the ICT examined in the previous subsection, we now explore their impact on firm performance, measured by turnover, employment, and productivity.

We begin by examining the immediate impact of technology adoption. This analysis is conducted for the entire economy, as well as separately for the manufacturing and services sectors. A treated firm is defined as one that did not use a given technology in period $t-1$ but began using it in period t. In contrast, a control firm is a matched non-treated firm that did not use the technology in either period t–1 or period t.[8] Focusing on the immediate effect has the advantage of not requiring the definition of treatment status in subsequent periods. Given that many firms participate in only a limited number of consecutive survey rounds, this approach allows us to maintain a relatively large sample. Accordingly, the number of adopters is as follows: 251 for websites, 349 for web-based sales, and 217 for EDI-based sales. As we will show, the number of firms in the sample decreases when we extend the analysis to periods $t+1$ and $t+2$.

Table 2 presents the estimates of $\beta_{1,0}$ from the difference-in-differences equation 2, across different technology types and economic sectors. Panel A summarises the results on the effects of webpage adoption on firm performance. At the aggregate level, webpage adoption is associated with a positive impact on total turnover and employment for the treated firms compared to control firms. These positive effects are observed in both the manufacturing and services sectors, with the impact being relatively stronger in the former. These findings support the notion that adopting new technology enhances labour demand and has an immediate positive effect on firm turnover. Regarding labour productivity, the immediate effects appear positive but are weak and statistically insignificant, suggesting that productivity gains may take longer to materialise following technology adoption. These results align with previous studies in the literature (Gal et al. (2019) for 20 countries; Dhyne et al. (2018) for Belgium; DeStefano et al. (2018) for the United Kingdom; Abidi et al. (2023) for 13 countries; Monteiro et al. (2021) for Portugal). The positive effect on employment suggests that the beneficial spillover effects of webpage adoption outweigh any short-term labour displacement,

[8] Matching quality is documented in Tables A.1, A.2, and A.3 in the Appendix. The matching procedure successfully ensured that treated and control firms are statistically comparable across a range of indicators.

Table 2: Technology adoption effects in t

		(1) Turnover	(2) Labour	(3) Productivity
Panel A: Webpage				
Total economy	β_1	0.066**	0.053***	0.021
	N	1058	1058	973
Manufacturing	β_1	0.097**	0.062**	0.043
	N	434	434	410
Services	β_1	0.056*	0.045**	0.014
	N	583	583	538
Panel B: Web sales				
Total economy	β_1	0.009	-0.013	-0.020
	N	1733	1733	1674
Manufacturing	β_1	0.026	-0.044	0.039
	N	528	528	510
Services	β_1	-0.020	-0.002	-0.037
	N	1251	1251	1212
Panel C: EDI sales				
Total economy	β_1	0.038*	0.023*	-0.009
	N	1170	1170	1154
Manufacturing	β_1	0.035	0.052***	-0.071*
	N	353	353	349
Services	β_1	0.061**	0.028*	0.043
	N	821	821	811

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, year and sector dummies are included.
Note: Under the definition of treatment, a treated firm is one that did not use a technology in period t–1 and started using it in t, while a control firm is defined as one that did not use the technology in both period t–1 and period t.

consistent with findings from certain studies in the literature (DeStefano et al. (2018) for the United Kingdom; Abidi et al. (2023) for 13 countries; Arntz et al. (2022) for Germany).

With respect to web sales, the point estimates are close to zero and statistically insignificant across all sectors and outcome variables. While the estimates suggest a larger effect of web sales adoption on turnover and employment in the manufacturing sector compared to services, Figure 3 does not indicate a systematically stronger engagement of Latvian firms in web sales within manufacturing relative to services. The absence of a significant estimated effect for web sales is somewhat puzzling given the existing literature. However, the characteristics of our dataset, combined with numerous alternative model specifications, consistently yield this result. As illustrated in Figure 2, web sales are predominantly utilised by small and medium-sized enterprises. One possible explanation is that investing in new technology may impose a relatively higher financial burden on smaller firms. Moreover, such investments often necessitate organisational changes, which can be costly in the short run. Given the one-year horizon of our analysis, this period may be too short for firms to fully absorb these short-term sunk costs, potentially leading to an initial decline in turnover.Additionally, smaller firms may adopt a "wait-and-see" strategy, introducing web sales on a limited scale to test their products in new markets. Over time, as firms gain market recognition and expand their customer base, sales volumes may increase, leading to a more dynamic turnover growth trajectory. Furthermore, our analysis highlights the importance of complementary investments in workforce skills. Latvian firms may be relatively successful in leveraging simpler and less costly technologies, such as setting up a webpage, but may struggle to integrate more advanced technologies due to a lack of complementary skills. This challenge may arise because larger firms have a greater ability to attract highly skilled workers, or due to a broader shortage of the necessary skills in the Latvian labour market. Finally, the negative effect on employment can be attributed to the short-term dislocation effect, whereby the adoption of new technologies temporarily disrupts labour demand within firms.

EDI sales are associated with positive effects on turnover and employment for treated firms. When analysed by sector, the turnover effect is observed in services, while employment creation is evident in manufacturing and services. However, the productivity-enhancing effects documented in the literature are not observed in the case of EDI sales. As shown in Figure 2, EDI adoption is predominantly concentrated among larger firms. The share of turnover generated from EDI sales, relative to web sales, is notably higher for large firms compared to smaller ones. Larger firms typically have greater access to financial resources, allowing them to more easily absorb the short-term costs associated with adopting complex technologies such as EDI. Additionally, they are better positioned to attract skilled labour and possess the requisite expertise to implement sophisticated technological solutions. Taken together, these factors suggest that the observed positive effects on turnover and employment at the aggregate level are likely driven by larger firms, even within the one-year time frame examined in this study.

Our analysis does not identify a positive and significant effect of any of the technologies studied on productivity. This finding aligns with certain studies in the existing literature, as discussed in Section 2 (Acemoglu et al. (2014) for the United States; Bartelsman et al. (2017); DeStefano et al. (2018) for the United Kingdom). One possible explanation is that the time horizon of our study is too short to capture productivity-enhancing effects, given that such improvements typically materialise with a considerable lag. Several studies suggest that the full impact of ICT adoption on productivity may take approximately 5 to 7 years to unfold (Brynjolfsson and Hitt (2000); Brynjolfsson and Hitt (2003)). As highlighted in the literature, ICT investments must be complemented by organisational restructuring and workforce upskilling to fully translate into productivity gains. This implies that firms require time to implement the necessary organisational frameworks and internal production adjustments before ICT adoption can yield measurable productivity improvements. Additionally, the short-term costs of both ICT implementation and organisational transformation may be prohibitively high, particularly for smaller firms, preventing them from making the necessary investments in organisational capital (Biagi (2013)). In other words, smaller firms may make inefficient use of ICT due to the lack of complementary organisational capital, making it more challenging to convert technology adoption into productivity gains. Instead, these firms may experience increased costs in the short run, delaying productivity improvements, or even facing temporary negative effects. This argument is particularly relevant in the case of Latvian firms, which are predominantly small to medium-sized and often face financial constraints. As a result, it is primarily larger firms and firms in specific sectors that possess the necessary expertise to effectively implement new technologies.

6.2 Dynamic effects of ICT adoption

Next, we extend our analysis to periods $t+1$, albeit at the cost of a substantial reduction in the number of observations. Due to this reason, the extended analysis is conducted for the total economy only. For the $t+1$ analysis, a treated firm is defined as one that did not use a given technology in period $t-1$, adopted it in period t, and continued using it in $t+1$. A control firm is a matched non-treated firm that did not adopt the technology in any of the three periods ($t-1$, t, or $t+1$). Under this strict definition, we lose approximately 50–65 percent of treated firms, depending on the specific ICT examined.[9]

To mitigate this loss of sample size, we adopt an alternative definition. As noted earlier, many firms do not participate in consecutive survey rounds. For firms that dropped out of the survey in $t+1$, we do not observe whether they continued using the technology. We therefore make the following assumption: if a firm adopted the technology in period t and we can confirm that it did not appear among the non-adopters in $t+1$ (i.e., it either continued using the technology or did not participate in the survey in $t+1$), we classify it as a treated firm. Similarly, a control firm is defined as one that did not use the technology in period t and for which we can confirm it was not among the adopters in $t+1$ (i.e., it either continued not using the technology or did not participate in the survey in $t+1$). This assumption is not without caveats, particularly with respect to control firms.[10] If newly adopting firms in $t+1$ are inadvertently included in the control group, we may observe a scenario where a strong positive effect in period t is followed by a weaker or statistically insignificant effect in $t+1$. Nevertheless, the results presented in Table A.4 suggest that the positive effect of webpage adoption on turnover and employment identified for period t persists into the subsequent period and, in fact, appears to strengthen.

[9] The matching procedure employed in the analysis presented in this section successfully ensured statistical comparability between treated and control firms across a range of indicators. Detailed results are available upon request.

[10] We believe that it is less likely for a firm that has already adopted ICT to later abandon its use than for a firm yet to embrace the technology to initiate its adoption.

When comparing this new set of results with those previously reported in Table 2, the effect of web page adoption remains positive and statistically significant, confirming earlier findings. Moreover, the effect of web sales adoption continues to be statistically insignificant. The effect of EDI-based sales adoption, which was weakly significant in period t (as shown in Table 2), now loses its significance, particularly when the baseline definition is applied, which excludes approximately half of the treated firms.

Finally, we extend the analysis to assess the effects in periods $t + 1$ and $t + 2$. However, the loss of observations becomes even more pronounced at this stage. Applying the strict definition of treatment - where the treated firms are required to have used the ICT in all three periods, and control firms in none - we are left with only 23 webpage adopters, 78 web sales adopters, and 51 EDI sales adopters. Despite the reduced sample size, the estimation results, presented in Table A.5, continue to confirm a positive effect of webpage adoption.

7 Conclusions

Using firm-level responses to the digitalisation survey, covering data on several types of technologies, this paper studies the reasons behind the slow technology adoption rates by Latvian firms. The study finds that the determinants for the use and adoption of a new technology, vary depending on the type of the technology studied. In general, larger firms, exporters, and those employing ICT specialists and highly skilled employees are more likely to have already adopted or to adopt new technologies. Competitive pressure from inside the industry, coupled with spillover effects, seem to matter as well. Age and foreign ownership do not exhibit a stable effect. Finally, offering ICT training to non-ICT specialists appears to be crucial for most types of the technologies examined here, with the role of training for ICT specialists becoming more important when a firm uses or adopts more complex types of ICT.

Next, we look into the effects of technology adoption on three firm performance indicators: turnover, labour, and productivity. We find that the introduction of a webpage boosts firm turnover and labour demand for total economy (including both the manufacturing and services sectors). Web sales are not found to have a statistically significant effect on any outcome variable or sector. Finally, EDI sales are found to be turnover and labour enhancing for the firms adopting them. In our study, we find no productivity enhancing effect for any of the technologies considered. The productivity paradox has been highlighted and explained by recent literature. Investments in ICT take time to materialise into productivity gains. Moreover, given that Latvian firms are characterised by small size, they might find it more difficult to finance the ICT and the related organisational and human capital investments needed in the short run. In the short run, the effects of the new technology on turnover, productivity and labour might even be negative. This might explain the absence of any statistical effect for web sales within the one year period we study.

The results highlight the need for Latvian firms to invest not only in new technologies, but also in organisational and human capital to fully unlock the positive impact on firm performance. Therefore, education policies that aim to encourage nationwide specialisation in ICT and general-purpose skills aligned with business needs are recommended.

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8 Appendix

Table A.1: Quality of matching for webpage adoption in total economy in t

Variable	Unmatched			Matched		
	Treated	Control	p-value	Treated	Control	p-value
Age	12.876	14.175	0.020	12.876	13.025	0.845
Log (turnover)	13.727	13.364	0.000	13.727	13.695	0.763
Log (labour productivity)	9.393	9.218	0.001	9.393	9.408	0.841
Log (employment)	3.17	3.051	0.018	3.17	3.136	0.642
Log (capital-to-labour ratio)	8.541	8.091	0.003	8.541	8.569	0.873
Exporting dummy	0.215	0.168	0.062	0.215	0.204	0.759
Earnings above industry median	0.478	0.367	0.000	0.478	0.490	0.694
ICT employment dummy	0.171	0.079	0.000	0.171	0.149	0.495

Notes: All variables are lagged. t-test for mean values of treated vs control firms. Matching has been performed using the 5 nearest neighbours method, among firms within the same two-digit NACE industry: 1791 on support, 251 treated firms, 807 controls.

Table A.2: Quality of matching for web sales adoption in total economy in t

Variable	Unmatched			Matched		
	Treated	Control	p-value	Treated	Control	p-value
Age	15.097	14.959	0.742	15.097	14.856	0.677
Log (turnover)	14.736	14.29	0.000	14.736	14.737	0.997
Log (labour productivity)	9.723	9.598	0.006	9.723	9.724	0.995
Log (employment)	3.754	3.586	0.009	3.754	3.766	0.904
Log (capital-to-labour ratio)	8.532	8.602	0.543	8.532	8.498	0.817
Exporting dummy	0.404	0.344	0.022	0.404	0.399	0.890
Earnings above industry median	0.539	0.492	0.011	0.539	0.563	0.351
ICT specialist dummy	0.415	0.269	0.000	0.415	0.437	0.572

Notes: All variables are lagged. t-test for mean values of treated vs control firms. Matching has been performed using the 5 nearest neighbours method, among firms within the same two-digit NACE industry: 7201 on support, 349 treated firms, 1384 controls.

Table A.3: Quality of matching for EDI sales adoption in total economy in t

Variable	Unmatched			Matched		
	Treated	Control	p-value	Treated	Control	p-value
Age	15.327	14.906	0.422	15.327	15.122	0.775
Log (turnover)	15.219	14.288	0.000	15.219	15.182	0.822
Log (labour productivity)	9.844	9.613	0.000	9.844	9.838	0.945
Log (employment)	4.018	3.558	0.000	4.018	3.987	0.813
Log (capital-to-labour ratio)	8.683	8.541	0.321	8.683	8.707	0.894
Exporting dummy	0.452	0.334	0.000	0.452	0.444	0.878
Earnings above industry median	0.615	0.503	0.000	0.615	0.620	0.854
ICT specialist dummy	0.475	0.287	0.000	0.475	0.492	0.716

Notes: All variables are lagged. t-test for mean values of treated vs control firms. Matching has been performed using the 5 nearest neighbours method, among firms within the same two-digit NACE industry: 8292 on support, 217 treated firms, 953 controls.

Table A.4: Technology adoption effects in t and $t+1$

		(1) Turnover	(2) Turnover	(3) Labour	(4) Labour	(5) Productivity	(6) Productivity
		t	$t+1$	t	$t+1$	t	$t+1$
Panel A: Webpage							
Baseline definition	β_1	0.106**	0.175**	0.072**	0.081*	0.026	0.007
	N	353	353	353	353	323	351
Alternative definition	β_1	0.067**	0.145**	0.056***	0.134***	0.014	0.027
	N	968	960	968	961	898	946
Panel B: Web sales							
Baseline definition	β_1	-0.041	-0.031	-0.008	-0.036	-0.094***	-0.098***
	N	869	869	869	869	851	864
Alternative definition	β_1	-0.015	0.028	-0.017	-0.002	-0.044	0.008
	N	1480	1472	1480	1475	1444	1453
Panel C: EDI sales							
Baseline definition	β_1	0.036	0.020	-0.001	0.013	0.031	-0.062
	N	591	591	591	591	588	581
Alternative definition	β_1	0.008	0.034	0.013	0.063**	-0.007	-0.053
	N	928	924	928	925	917	905

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, year and sector dummies are included.
Note: Under the baseline definition of treatment, a treated firm is one that continued using the technology in period $t+1$, while a control firm is one that was still not using the technology in $t+1$. Under the alternative (more relaxed) definition, a treated firm is defined as one that adopted the technology in period t and for which we can confirm that it was not among the non-adopters in $t+1$ (i.e. it either continued using the technology or did not participate in the survey in $t+1$). Similarly, a control firm is defined as one that did not use the technology in period t and for which we can confirm that it was not among the users in $t+1$ (i.e. it either continued not using the technology or did not participate in the survey in $t+1$).

Table A.5: Technology adoption effects in t, $t+1$ and $t+2$

		(1) Turnover	(2)	(3)	(4) Labour	(5)	(6)	(7) Productivity	(8)	(9)
		t	$t+1$	$t+2$	t	$t+1$	$t+2$	t	$t+1$	$t+2$
Panel A: Webpage										
Baseline definition	β_1	0.099	0.119	0.036	0.132**	0.159**	0.164*	0.118	-0.079	-0.135
	N	91	91	91	91	91	91	86	91	91
Alternative definition	β_1	0.112**	0.189***	0.054	0.074**	0.084*	0.007	0.016	0.042	0.059
	N	347	347	343	347	347	344	322	345	337
Panel B: Web sales										
Baseline definition	β_1	-0.022	-0.037	-0.057	-0.179	-0.042	-0.073**	-0.066	-0.028	-0.084
	N	355	355	355	355	355	355	347	350	351
Alternative definition	β_1	-0.020	-0.027	-0.016	-0.015	-0.039	-0.034	-0.068*	-0.121**	-0.058
	N	723	723	571	723	723	571	711	718	566
Panel C: EDI sales										
Baseline definition	β_1	-0.007	-0.046	-0.050	-0.021	-0.018	-0.066	-0.006	-0.109*	-0.017
	N	591	591	591	591	588	581			
Alternative definition	β_1	0.037	0.008	0.055	-0.007	-0.005	-0.060	0.037	-0.025	0.065
	N	490	490	381	490	490	382	487	480	370

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, year and sector dummies are included.

Note: Under the baseline definition of treatment, a treated firm is one that continued using the technology in period $t+2$, while a control firm is one that was still not using the technology in $t+2$. Under the alternative (more relaxed) definition, a treated firm is defined as one that adopted the technology in period t and $t+1$ but for which we can confirm that it was not among the non-adopters in $t+2$ (i.e. it either continued using the technology or did not participate in the survey in $t+2$). Similarly, a control firm is defined as one that did not use the technology in period t and $t+1$ but for which we can confirm that it was not among the users in $t+2$ (i.e. it either continued not using the technology or did not participate in the survey in $t+2$).