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ECONOMICS DEPARTMENT

COVID-19 AND PRODUCTIVITY-ENHANCING DIGITALISATION: FIRM-LEVEL EVIDENCE FROM SLOVENIA

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ABSTRACT

COVID-19 and productivity-enhancing digitalisation: Firm-level evidence from Slovenia

This paper provides evidence on the impact of digitalisation on productivity in Slovenia during the COVID-19 crisis. The pandemic affected overall labour productivity negatively. Nonetheless, results show that firms that were more ICT-intensive before the pandemic experienced a smaller decline in their labour productivity growth compared to their less ICT-intensive peers in the same 2-digit level sector. This resilience effect was strongest for firms that are integrated in global value chains. A second finding is that COVID-19 resulted in productivity-enhancing reallocation of labour to ICT-intensive firms, reflecting that these firms registered higher employment growth relative to their less ICT-intensive peers during the pandemic. A third finding is that high levels of state ownership in a sector was associated with less productivity-enhancing reallocation. This suggests that state-owned enterprises retained workers that could be redirected to more productive firms. Together, these findings highlight the potential of digitalisation to support resilience and stronger productivity growth, although labour market rigidities and state ownership hamper the positive impact of digitalisation.

JEL classification codes: D24; E22; E24; O33

Keywords: digitalisation, productivity, labour reallocation

This Working Paper relates to the 2022 OECD Economic Survey of Slovenia, https://www.oecd.org/economy/slovenia-economic-snapshot/.

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COVID-19, la numérisation et la productivité: une analyse sur données des entreprises de la Slovénie

Cet article analyse le rôle de la numérisation sur la productivité en Slovénie pendant la crise du COVID-19. La pandémie a eu un effet négatif sur la productivité. Néanmoins, les résultats montrent que les entreprises qui étaient plus intensives en TIC avant la pandémie ont connu une baisse plus faible de la croissance de leur productivité par rapport à leurs homologues moins intensives en TIC dans le même secteur. Cet effet de résilience est le plus fort pour les entreprises intégrées dans les chaînes de valeur mondiales. Une deuxième constatation est que la COVID-19 a entraîné une réaffectation de la main-d'œuvre vers les entreprises à forte intensité de TIC, ce qui a amélioré la productivité, ce qui montre que ces entreprises ont enregistré une croissance de l'emploi plus élevée par rapport à leurs homologues moins intensives en TIC pendant la pandémie. Une troisième constatation est que des niveaux élevés de propriété de l'État dans un secteur ont réduit la réaffectation qui améliorait la productivité. Cela suggère que les entreprises publiques ont retenu des travailleurs qui pourraient être redirigés vers des entreprises plus productives. Ensemble, ces résultats mettent en évidence le potentiel de la numérisation pour soutenir la résilience et une croissance plus forte de la productivité, bien que les rigidités du marché du travail et la propriété de l'État entravent l'impact positif de la numérisation.

Classification JEL: D24; E22; E24; O33

Mots Clés: numérisation, productivité, réaffectation de la main-d'œuvre

Ce Document de travail a trait à l'Étude économique de l'OCDE de la Slovénie 2022 https://www.oecd.org/fr/economie/slovenie-en-un-coup-d-oeil/.

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COVID-19 and productivity-enhancing digitalisation: Firm-level evidence from Slovenia

By Martin Borowiecki, Federico Giovannelli and Jens-Christian Høj[1]

Introduction

Enhancing productivity growth is key to sustain income convergence in Slovenia. Stronger productivity growth can be achieved through the broader uptake of digital solutions among enterprises, particularly to accelerate the digital transformation of the economy (Gal et al., 2019[1]; Borowiecki et al., 2021[2]). Across the OECD, the COVID-19 crisis has tended to accelerate the digital transformation. Many firms had to rapidly step up their IT capacities and introduce telework and other digital solutions to continue operating, which strengthened their resilience to the economic shock and gave them an advantage over less digitalised firms. In Australia and the United Kingdom, for instance, high-productivity and more digitalised firms were more likely to expand employment, while low-productivity firms were more likely to exit the market (Andrews, Charlton and Moore, 2021[3]). However, evidence on the impact of digitalisation on productivity in Slovenia during the pandemic is missing.

The impact of digitalisation on productivity may be lower in Slovenia than in OECD countries with higher productivity growth due to several factors. First, state-involvement is widespread in many sectors. High levels of state ownership may limit labour reallocation as state-owned enterprises (SOEs) retain workers that could be redirected to more productive activities (OECD, 2020[4]). Second, co-ordinated wage bargaining at the sector level ensures that workers receive similar wage increases within a very compressed wage structure, creating a disconnection between individual productivity and wages. This leaves workers with few incentives to change job (OECD, 2020[4]; OECD, 2022[5]). More efficient labour reallocation can support further digitalisation as scarce labour resources, which are crucial for implementing digital technologies, are freed up in underperforming firms to the benefit of more digitalised and productive firms (Andrews, Charlton and Moore, 2021[3]; Criscuolo et al., 2021[6]).

This paper aims at uncovering evidence on the impact of digitalisation on firm-level resilience and productivity-enhancing labour reallocation during the pandemic in Slovenia. The analysis builds on a unique dataset of Slovenian enterprises that covers service sector and manufacturing firms, and is, to the authors' knowledge, the first paper to investigate the link between firm-level productivity, within sector

[1] Martin Borowiecki, Federico Giovannelli and Jens Høj are members of the OECD Economics Department. The corresponding author is Martin Borowiecki (Martin.Borowiecki@oecd.org). The paper has benefited from comments and suggestions from Mame Fatou Diagne, Timo Leidecker, Douglas Sutherland, Sébastien Turban (with the OECD Economics Department), Nathalie Scholl (with the OECD Directorate for Science, Technology and Innovation) and Gregor Zupan (with the Statistical Office of the Republic of Slovenia). Gemma Martinez provided valuable editorial assistance.

labour reallocation and digitalisation in a Slovenian context. The paper uses a difference-in-difference approach to estimate effects of digitalisation – measured in terms of pre-crisis ICT investment, on firm-level resilience and labour reallocation before and during the pandemic, following Andrews *et al*. (2021[3]). The pandemic offers a unique setting to study the impact of digitalisation, as firms that had heavily invested in digital before the crisis were able to use digital solutions such as online sales channels and remote working to a higher extent than their less digitalised peers, especially during the first wave that saw most on-site production affected. The analysis is conducted within sectors at the 2-digit NACE level to account for cross-sector productivity differences and the fact that low-productivity firms may specialise in activities or sectors that are more difficult to digitalise. Accounting for sector differences is also important as some sectors were more heavily affected by the pandemic.

The findings show that firms generally saw a contraction in their productivity growth during the pandemic, but firms that were more ICT-intensive before the pandemic were more resilient to the economic shock and experienced more limited losses to their labour productivity growth, while productivity growth of their less ICT-intensive peers contracted more strongly. The resilience effect is strongest for firms that are integrated in global value chains, pointing to potential benefits from access to global markets and international technology transfer. However, the findings on the resilience effect during the COVID crisis are not necessarily applicable to productivity effects after the crisis as the pandemic was an exceptional shock to the economy, due to both its nature and its size.

Furthermore, COVID resulted in productivity-enhancing reallocation of labour to ICT intensive firms. ICT-intensive and high productivity firms were more likely to continue hiring, while low productivity firms were more likely to fire people during the pandemic.

The findings also point to important factors hampering the positive impact of digitalisation. Investment in ICT does not lead to higher wage growth relative to non-ICT intensive firms, despite higher productivity of ICT-intensive firms. Moreover, high levels of state ownership in a sector limit productivity-enhancing labour reallocation, suggesting that state-owned enterprises retain workers that could be redirected to more productive firms. Policy can support digitalisation through privatisations and a more decentralised wage-setting system that allow a smooth reallocation of labour to productive enterprises that use digital solutions.

The remainder of the paper is structured as follows: The next section describes the data and the empirical methodology. The third section presents empirical results. The fourth section discusses the main results and concludes.

1. Data and methodology

Data and variables

The analysis is based on administrative and business survey data from the Statistical Office of Slovenia (Table 1). The sample of Slovenian enterprises consists of 4 187 firms with 5 or more employees for the years 2016 to 2020. These are firms observed at least once in the five-year period from 2016 to 2020. To construct the sample, administrative firm-level data from the Business Register and the Annual Accounts of Slovenia were matched. The Business Registry provides information on the date of establishment of an enterprise, its ownership and the detailed 2-digit level NACE sector. Annual Accounts provide information on labour productivity, employment, wages and exports. This dataset was then linked with the Investment Survey, which provides firm-level information on investment in fixed assets and ICT. Finally, the resulting dataset was matched with firm-level information on usage of digital solutions from the ICT Usage and E-commerce in Enterprises Survey (ICT Survey). The Investment Survey and the ICT Survey are based on a representative sample of Slovenian enterprises. The resulting sample of firms captures a quarter of all employees in Slovenia in 2020.

The above-described matching process produces detailed firm-level data on performance, investments, and ICT usage. However, a downside of the approach is some bias towards manufacturing as well as medium-sized and larger firms, reflecting their better coverage in investment and ICT business surveys. Manufacturing sector firms are overrepresented, with an employment share of 49% in the sample as compared to a share of 40% in the administrative dataset. Similarly, medium-sized and larger firms are overrepresented in the sample with employment shares of 16% and 79%, respectively, compared to employment shares of medium-sized and larger firms in the administrative data of 26% and 38%, respectively.

Table 1. Description of variables

Variable	Description	Level	Coverage	Source
Dependent variables				
Labour productivity growth	Labour productivity growth calculated as real value added divided by the number of employees	Enterprise	2017-2020	Annual accounts
Employment growth	Growth in the number of employees (full-time equivalents)	Enterprise	2017-2020	Annual accounts
Wage growth	Growth in real gross wages per worker (gross wages and salaries divided by the number of employees)	Enterprise	2017-2020	Annual accounts
Digital variables				
Digital infrastructure				
ICT investment per worker	The log of real investment in ICT hardware, software and data, divided by the number of employees	Enterprise	2016-2020	Investment Survey
Broadband (>100Mb/s)	Dummy variable = 1 if the maximum contracted download speed of the fastest internet connection is at least 100 Mbit/s	Enterprise	2016-2020	ICT Survey
Digital solutions				
Website for booking	Dummy variable = 1 if the firm has a website for online ordering, reservation or booking	Enterprise	2016-2020	ICT Survey
Turnover from e-commerce	Percentage of turnover generated by web sales of goods or services, and from orders that were placed via EDI-type messages in the previous year	Enterprise	2016-2020	ICT Survey
Cloud computing	Dummy variable = 1 if the firm buys cloud computing services used over the internet	Enterprise	2016, 2017, 2018, 2020	ICT Survey
Robots	Dummy variable = 1 if the firm uses industrial and/or service robots	Enterprise	2017, 2019	ICT Survey
E-invoices	Dummy variable = 1 if the firm sent more than 10% of its invoices in electronic form, in a standard structure suitable for automated processing (e-invoices) in the previous year	Enterprise	2018, 2020	ICT Survey
Social media	Dummy variable = 1 if the firm uses any of the following social media: a) social networks (e.g., Facebook, LinkedIn, etc.), b) blogs or microblogs (e.g., Twitter, etc.), c) multimedia content sharing websites or apps (e.g., YouTube, Instagram, etc.), and/or d) Wiki-based knowledge sharing tools	Enterprise	2016, 2017, 2019	ICT Survey
CRM front-office Software	Dummy variable = 1 if the enterprise uses Customer Relationship Management (CRM) software solutions	Enterprise	2017, 2019, 2020	ICT Survey
ERP front-office Software	Dummy variable = 1 if the enterprise uses Enterprise Resource planning (ERP) software solutions	Enterprise	2017, 2019, 2020	ICT Survey
ICT usage by workers and training				
Share of workers with internet access	The share of employees with access to the internet for business purposes	Enterprise	2016-2020	ICT Survey
Share of workers with mobile device with internet	The share of employees with a portable device (laptop, tablet, smartphone) that allows internet connection via mobile internet networks for business purposes	Enterprise	2016-2020	ICT Survey
ICT training	Dummy variable = 1 if the firm provided any type of training to develop ICT-related skills of employees in the previous year	Enterprise	2016-2019	ICT Survey

Control variables				
Frontier growth	Average labour productivity growth of the top 5 percent firms in each sector and year	Enterprise	2016-2019	Annual accounts
Labour productivity gap to frontier	Distance to the frontier (based on log labour productivity levels)	Enterprise	2016-2019	Annual accounts
Capital per worker	The log of real investment in fixed assets, excluding ICT investment, divided per the number of employees	Enterprise	2016-2020	Investment Survey
Export share	The share of net revenues from exports	Enterprise	2016-2020	Annual accounts
Firm age	The log of the firm's age calculated as the difference between the current year and the year of establishment (based on the date of entry in the Business Registry)	Enterprise	2016-2020	Business Register of Slovenia
Firm size	Dummy categories for the size of the firm based on employment: small (5-49 employees); medium (50-249 employees) or large (250 or more employees)	Enterprise	2016-2020	Annual accounts
Variables for additional analysis				
Ownership type	Dummy categories for the type of ownership of the firm as state-owned (including partly-state-owned) or private (including foreign)	Enterprise	2016-2020	Business Register of Slovenia
Export-oriented/ domestically-oriented	Dummy categories for the export-orientation of the firm (with 35% or more of revenues generated by exports) or domestically-oriented (less than 35% of revenues generated by exports)	Enterprise	2016-2020	Annual accounts
Manufacturing/ services	A dummy for whether the firm's main activity is in manufacturing (NACE Rev.2 10-33) or services (NACE Rev.2 45-82)	Enterprise	2016-2020	Business Register of Slovenia
Start-up/ incumbent firm	A dummy capturing firm age as start-up (established in 2009 of after) and incumbent (before 2009)	Enterprise	2016-2020	Business Register of Slovenia
SOE employment share	Share of employment in state-owned (and partly state-owned) enterprises	Sector	2016-2020	Annual accounts and Business Register of Slovenia

Note: Growth rates correspond to year-on-year % changes.

The unbalanced enterprise panel contains detailed information on value added and employment, which are needed to construct measures of labour productivity. The dependent variables are firm-level labour productivity growth, employment growth and growth of the average wage per worker. Employment is calculated as the number of persons employed by the firm (full-time equivalent). To compute the average wage per employee, the firm-level wage bill is divided by the number of employees.

The panel further includes independent variables on the firms' investment in ICT hardware, software and data, and whether the enterprise has a high-speed broadband connection with at least 100 Mbit/s (high-speed broadband). Other independent variables capturing digitalisation include employees' ICT use and training among workers, including the share of employees with access to the internet for work purposes, the share of employees using a mobile device (laptop, table or smartphone) to access the internet for work purposes, and whether the firm has offered ICT training to its employees.

Furthermore, additional independent variables capture the use of several specific digital solutions, including cloud computing, social media or electronic invoices (e-invoices). They also cover whether firms use industrial or service robots. Another aspect covered includes whether firms have a website and whether they use front-office software for Customer Relationship Management (CRM) and Enterprise Resource Planning (ERP). And finally, given the importance of e-commerce during the pandemic, additional variables include the share of turnover generated from e-commerce and Electronic Data Interchange (EDI)-type sales of goods or services. The latter refers to orders that are automatically placed and processed using computer-to-computer communication, based on a standard data exchange format.

In addition, the analysis controls for various firm-level characteristics that may also explain productivity and employment dynamics. For instance, larger, more capital-intensive and export-oriented firms may have

higher productivity and wage dynamics than their smaller, domestically-oriented peers. These factors may explain productivity growth and employment growth rather than digitalisation. Firm-level controls include age, size (small, medium and large enterprise), export sales, investment in fixed assets (excluding hardware and software investment), and whether the firm is state- or privately owned.

A log transformation was applied to productivity, employment, wage and investment variables to estimate percent changes in labour productivity growth, employment growth and wage growth per percent change in ICT investment. In order to calculate real value added, real wages and real investment series, nominal value added, nominal wages and nominal investment were deflated separately using value added, consumer price and gross fixed capital formation deflators, respectively, taken from Eurostat National Account Statistics. Furthermore, the analysis tests for heterogeneity of effects across broad sectors, firm size classes, incumbent firms versus start-ups, and state-owned enterprises versus privately-owned enterprises. Finally, following previous OECD literature (Gal et al., 2019[1]), this analysis covers firms only in manufacturing and service sectors, excluding agriculture, forestry and fishing, financial and insurance activities, public administration, defence, education, human health and social work activities. The descriptive statistics are shown in (Table 2).

Table 2. Descriptive statistics

	Mean	Standard deviation	Observations
Unbalanced panel with 4 187 firms over 5 years (2016-2020)			
Dependent variable			
Labour productivity growth	-0.01	0.30	10721
Employment growth	0.03	0.19	10809
Wage growth	0.02	0.10	10809
Control variables			
Frontier growth	0.00	0.16	10809
Gap to frontier (log)	0.93	0.57	18787
Capital per worker (log)	11.13	3.01	8814
Export share	0.47	0.35	8493
Firm age (log)	2.76	0.75	18801
Small enterprise	0.66	0.47	18964
Medium-sized enterprise	0.27	0.44	18964
Large enterprise	0.06	0.23	18964
Digital variables			
ICT infrastructure			
ICT investment per worker (log)	3.90	3.32	8814
Broadband (>100Mb/s)	0.31	0.46	5805
Digital solutions			
Website for booking	0.24	0.43	6495
Turnover from e-commerce	0.12	0.22	167
Cloud computing	0.34	0.47	5866
Robots	0.12	0.32	2898
E-invoices	0.39	0.49	1909
Social media	0.55	0.50	4459
CRM front-office	0.31	0.46	4381
Software	0.44	0.50	4381
ICT usage by workers and training			
Share of workers with internet access	0.56	0.34	7361
Share of workers with mobile device with internet	0.27	0.29	7348
ICT training	0.38	0.49	7361

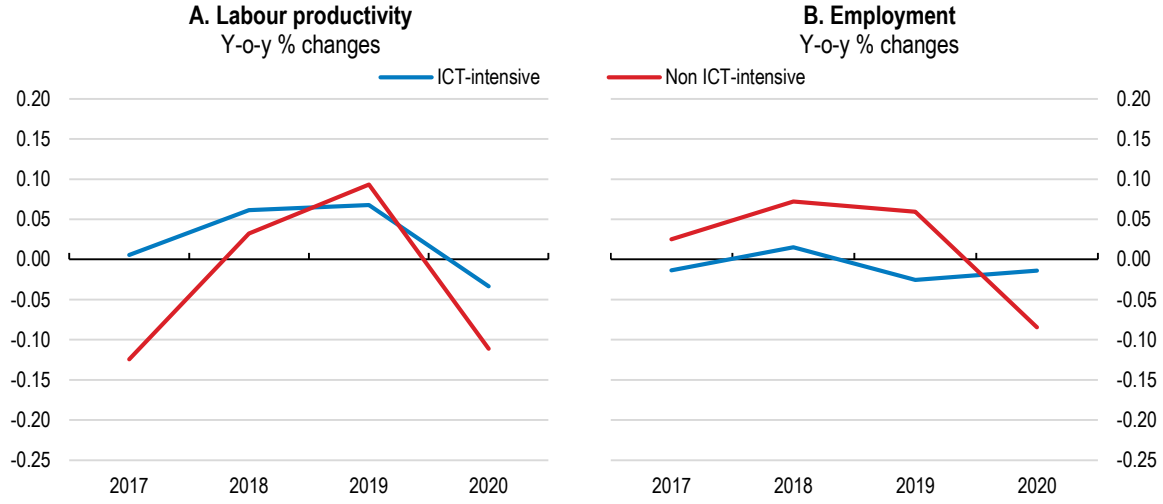
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Firm performance before and during the first waves of the pandemic

Figure 1 presents labour productivity and employment growth rates for ICT-intensive and non-ICT-intensive firms over the period 2016 to 2020. Panel A shows that in the years before the pandemic, both ICT-intensive firms and non-ICT-intensive firms registered on average strong labour productivity growth. When the pandemic hit in 2020, productivity growth of non-ICT-intensive firms fell by about 11 percentage points. Productivity growth of ICT-intensive firms also fell but these firms managed to limit the productivity decline. The stronger resilience of ICT-intensive firms during the pandemic is not driven by high-productivity manufacturing firms or low-productivity firms in the most affected hospitality sector (see Figure C.1 in the Annex).

Regarding employment, ICT-intensive firms had lower employment growth than non-ICT-intensive firms during the pre-COVID economic upswing (Panel B). With the onset of the pandemic in 2020, employment growth fell for non-ICT-intensive firms, while the decline in employment growth for ICT-intensive firms was limited. Again, the better employment performance of ICT-intensive firms during the pandemic occurred across all sectors (see Figure C.1 in the Annex).

Figure 1. Productivity and employment growth, ICT-intensive versus non-ICT-intensive firms



Note: ICT-intensive firms have an ICT investment share (in total investment) of 0.05% (median) or higher.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Empirical approach

Empirical model for estimating productivity effects

The estimation shown in Equation 1, follows the approach applied in several OECD studies that estimate firm-level productivity growth, e.g., Gal *et al*. (2019[1]). Growth in labour productivity for non-frontier firms (i.e., excluding top 5% most productive firms within a 2-digit level NACE sector, see below) is assumed to follow the following process:

$$\Delta LP_{i,s,t} = \alpha_1 \Delta LP_{frontier,s,t} + \alpha_2 gap_{i,s,t-1} + \alpha_3 ICT_{i,s,t-1} + \alpha_4 Z_{i,s,t-1} + \eta_s + \tau_t + \varepsilon_{i,s,t} \quad (1)$$

where $gap_{i,s,t-1} = LP_{frontier,s,t-1} - LP_{i,s,t-1}$

$\Delta LP_{i,s,t}$ is labour productivity growth of non-frontier firm i in sector s and in year t measured by real value added divided by employees. In line with previous OECD work, the sample of non-frontier firms excludes the frontier firms, which are the 5 percent most productive firms in each sector (s) and year (t) as high

productivity firms may be responsible for most productivity growth and ICT investment (Gal et al., 2019[1]). This approach also allows to test whether non-frontier firms such as most domestic SMEs are catching up to the productivity frontier. Firm-level labour productivity growth is assumed to depend on labour productivity growth of frontier firms ($\Delta LP_{frontier,s,t}$), and on the lagged distance to the frontier firms ($gap_{i,s,t-1}$). The productivity frontier is expected to raise productivity growth in other firms with a factor below one, so that the value of α_1 is expected to be lower than 1 as innovation at the frontier benefits other firms via technology transfer, but only partially. Economic theory predicts catch-up of follower firms to the frontier, measured by a positive value of α_2 (Berlingieri et al., 2020[7]).

$ICT_{i,s,t-1}$ is a vector of variables measuring the firm's digitalisation. The coefficient of interest is α_3, which captures the effect of ICT investment and the use of digital solutions on firm-level productivity growth. Separate regressions are estimated for each digital variable.

$Z_{i,s,t-1}$ is a vector of firm-level control variables, including investment in physical capital per worker (excluding ICT investment), exports, age, size, sector and ownership. As the model controls for physical capital, the coefficients can also be interpreted as effects on multi factor productivity. η_s and τ_t are NACE 2-digit level sector- and year-fixed effects that account for differences across narrow NACE 2-digit level sectors and annual time trends, respectively, and $\varepsilon_{i,s,t}$ is a random error term.

Empirical model for estimating labour reallocation dynamics

The empirical specification for estimating within-sector labour allocation consists of Equation 2 and 3. This empirical model has been applied in OECD studies, including Andrews *et al.* (2021[3]). Equation 2 regresses firm's investment in ICT on employment growth over the years 2016 through 2020 as follows:

$$\Delta E_{i,s,t} = \alpha_1 LP_{i,s,t-1} + \alpha_2 ICT_{i,s,t-1} + \alpha_3 Z_{i,s,t-1} + \eta_s + \tau_t + \varepsilon_{i,s,t} \quad (2)$$

while Equation 3 regresses firm's ICT investment on wage growth

$$\Delta W_{i,s,t} = \alpha_1 LP_{i,s,t-1} + \alpha_2 ICT_{i,s,t-1} + \alpha_3 Z_{i,s,t-1} + \eta_s + \tau_t + \varepsilon_{i,s,t} \quad (3)$$

where $\Delta E_{i,s,t}$ and $\Delta W_{i,s,t}$ is employment growth and wage growth, respectively, for firm i in sector s and in year t. Employment and wage growth are assumed to depend on firm's labour productivity ($LP_{i,s,t}$). The value of coefficient α_1 is expected to be positive as firms with higher productivity have higher labour demand, and are thus more likely to expand employment, consistent with productivity-enhancing labour reallocation (Cooper, Haltiwanger and Willis, 2007[8]). Workers in more productive firms should also receive higher wages (Carlsson, Messina and Skans, 2015[9]; Card, Devicienti and Maida, 2013[10]).

$ICT_{i,s,t-1}$ is a vector of variables measuring digitalisation. The coefficient of interest is α_2, which captures the effect of ICT investment and the use of digital solutions on firm-level employment growth and wage growth. It is expected to be positive as firms that invest more in ICT and use digital solutions are expected to have higher productivity, which translates into higher demand for labour and thus higher employment and wage growth. Separate regressions are estimated for each digital variable.

As before, $Z_{i,s,t-1}$ is a vector of firm-level control variables, including investment in physical capital per worker (excluding ICT investment), exports, age, size, sector and ownership. η_s and τ_t are sector- and year-fixed effects, respectively, and $\varepsilon_{i,s,t}$ is an independent and identically distributed random error term.

Identification strategy

Endogeneity is a concern for the identification of productivity, employment and wage effects of digitalisation. Endogeneity can occur from reverse causality, whereby a larger and capital-intensive firm invests more in ICT, or omitted variable bias, i.e., that there is an unobserved confounding factor that impacts both productivity, employment and/or a firm's digitalisation. Such a factor could be management skills (Criscuolo et al., 2021[11]; Calvino et al., 2022[12]). In the presence of such factors, the empirical model

would fail to identify the relationship between digitalisation, productivity, employment and wages, leading to biased estimates.

To address these challenges, the analysis adopts a difference-in-difference approach to test for the impact of digitalisation on, first, labour productivity growth, and second, employment and wage growth during the COVID-19 pandemic. The pandemic offers a unique natural experiment as it affected some firms more than others. Overall, the crisis affected aggregate labour productivity negatively. Nonetheless, firms that heavily invested in digital tools were able to work themselves through this pandemic faster, especially during the first wave that saw most physical production affected. Specifically, a difference-in-difference estimation model in Equation 4 is used to test whether, within a narrow 2-digit level NACE sector, more ICT-intensive firms experienced better outcomes in terms of productivity, employment and wage growth compared to less ICT-intensive firms during the crisis:

$$\Delta Y_{i,s,t} = \alpha_1 + \alpha_2 d_{2020} + \alpha_3 ICT_{i,s,2019} + \alpha_4 \left(d_{2020} \times ICT_{i,s,2019}\right) + \alpha_5 Z_{i,s,t-1} + \eta_s + \tau_t + \varepsilon_{i,s,t} \quad (4)$$

where the left-hand side variable $\Delta Y_{i,s,t}$ is the outcome variable for firm *i* in sector *s* and in year *t*. This outcome variable – labour productivity growth, employment growth, or wage growth, is regressed on variables measuring the firm's digitalisation in 2019, i.e., the year preceding the pandemic, $ICT_{i,s,2019}$. The variable d_{2020} is a dummy for 2020, the year the COVID-19 crisis hit the Slovenian economy. The coefficient of interest is α_4, which corresponds to the interaction term between the 2020 dummy and the firm's digitalisation in 2019, $ICT_{i,s,2019}$. For instance, in the case of ICT investment as measure of digitalisation, this interaction term measures whether firms that were more ICT-intensive before the pandemic experienced better outcomes in terms of productivity, employment and wage growth during the pandemic relative to their less ICT-intensive peers within the same sector.

$Z_{i,s,t-1}$ is a vector of firm-level control variables, including investment in physical capital per worker (excluding ICT investment), exports, age, size, sector and ownership. η_s and τ_t are sector- and year-fixed effects, and $\varepsilon_{i,s,t}$ is an independent and identically distributed random error term. Robustness tests include the estimation of a specification with sector-year fixed effects to control for time-varying shocks that differ across sectors (see below).

Further analysis provides evidence on differential productivity and employment effects across a) firm size, b) sectors, c) state-owned enterprises versus privately-owned enterprises, d) export- versus domestically-oriented firms, and e) incumbent enterprises versus start-ups.

2. Results

Firm-level productivity growth

ICT investment leads to higher productivity growth

Table 3 shows results from the OLS regressions of firm-level labour productivity growth on firm-level ICT investment and digital adoption for 2016-2020. Separate regressions are run for each digital variable (ICT investment, broadband, etc.). Results show that ICT investment is positively and statistically significantly associated with labour productivity growth of non-frontier firms during 2016-2020 (Column 1), while other digital variables are not (Columns 2-10). The only exception is the share of workers with a mobile device (laptop, smartphone, tablet) giving access to the internet for work purposes, albeit at low levels of significance.

Further findings show that both frontier growth and the lagged productivity gap to the frontier are associated with higher productivity growth. This suggests that there is a positive role of technology transfer for productivity growth of non-frontier firms stemming from the frontier and that less productive firms are

catching-up with the productivity frontier. Investment in physical capital (per worker) is also positively associated with labour productivity growth.

Table 3. OLS regression results for labour productivity growth

	ICT infrastructure		Digital solutions					ICT usage by workers and training		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	ICT invest-ment	Broad band (>100Mb/s)	Website for booking	Turnover from e-commerce	Cloud	Robots	E-invoices	Share of workers with internet access	Share of workers with mobile device with internet	ICT training
Digital variable[1]	0.007***	0.016	0.025	-0.104	-0.008	0.000	-0.003	0.058	0.073*	0.013
	(0.002)	(0.016)	(0.020)	(0.239)	(0.014)	(0.022)	(0.035)	(0.037)	(0.043)	(0.020)
Control variables										
Frontier growth	0.223***	0.238***	0.204***	0.165**	0.228***	0.000	0.000	0.207***	0.212***	0.201***
	(0.031)	(0.053)	(0.040)	(0.080)	(0.048)	(0.000)	0.000	(0.039)	(0.037)	(0.040)
Gap to the frontier (lagged)	0.280***	0.129**	0.146***	0.098	0.132**	0.202***	0.205***	0.155***	0.154***	0.148***
	(0.038)	(0.055)	(0.046)	(0.076)	(0.052)	(0.044)	(0.063)	(0.044)	(0.043)	(0.046)
Capital per worker	0.012**	0.010**	0.012***	0.014	0.013**	0.018**	0.016	0.012***	0.012***	0.012***
	(0.004)	(0.004)	(0.004)	(0.008)	(0.005)	(0.007)	(0.010)	(0.004)	(0.004)	(0.004)
Share of sales from exports	0.011	-0.005	0.007	0.044	0.030	0.032	0.052	0.017	0.017	0.009
	(0.014)	(0.027)	(0.025)	(0.092)	(0.031)	(0.039)	(0.065)	(0.027)	(0.027)	(0.025)
Firm age	0.002	0.015	0.012	0.024	0.018*	0.013	0.012	0.013	0.014	0.013
	(0.007)	(0.010)	(0.009)	(0.026)	(0.010)	(0.022)	(0.031)	(0.009)	(0.009)	(0.009)
Firm size (medium-sized enterprise)	-0.004	-0.007	0.000	0.022	-0.012	0.008	0.000	-0.002	-0.001	-0.004
	(0.014)	(0.019)	(0.020)	(0.046)	(0.024)	(0.041)	(0.065)	(0.019)	(0.019)	(0.019)
Firm size (large enterprise)	-0.035	-0.027	-0.027	-0.011	-0.038	-0.043	-0.068	-0.029	-0.028	-0.034
	(0.021)	(0.021)	(0.025)	(0.048)	(0.028)	(0.069)	(0.102)	(0.024)	(0.025)	(0.028)
Constant	-0.287***	-0.220***	-0.217***	-0.249	-0.231***	-0.298***	-0.258***	-0.255***	-0.238***	-0.221***
	(0.070)	(0.074)	(0.052)	(0.153)	(0.057)	(0.081)	(0.083)	(0.058)	(0.053)	(0.053)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3.132	783	1.034	188	777	263	170	1.046	1.046	1.046
R-squared	0.204	0.116	0.134	0.206	0.147	0.399	0.441	0.137	0.138	0.135

Note: [1] Digital variable denotes variables shown in the first row: ICT investment, broadband (>100Mbit/s), website for booking, turnover from e-commerce, cloud services, robots, e-invoices (in total invoices), share of workers with internet access for work purposes, share of workers with mobile device with internet access for work purposes (e.g., laptop, smartphone), and ICT training. Unreported results for social media, CRM and ERP front-office software are not significant.
The dependent variable is labour productivity growth of non-frontier firms (excl. top 5 percent firms in each sector-year cell). Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Main results highlighted.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Table 4 presents results from the difference-in-difference regressions of firm-level labour productivity growth in 2020 on firm-level ICT investment and digital adoption in 2019. Separate regressions were run for each digital variable (ICT investment, broadband, etc.). With overall labour productivity growth falling during the pandemic, results show that firms that had invested relatively more in ICT before the pandemic

managed to limit the decline to their labour productivity, while there was a 0.6 percentage point stronger fall in labour productivity growth of less ICT-intensive firms during 2020 (Column 1). As before, other digital variables are not statistically significant (Columns 2-10). The findings on control variables are similar to those of the OLS regression in Table 3, where the coefficient on frontier growth, lagged productivity gap and capital intensity is positive and statistically significant. This points to the positive role of technology transfers from the frontier, catch-up of non-frontier firms and capital intensity for firm-level productivity growth.

Table 4. Difference-in-difference regression results for labour productivity growth

VARIABLES	**ICT infrastructure**		**Digital solutions**					**ICT usage by workers and training**		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	ICT invest-ment	Broad band (>100Mb/s)	Website for booking	Turnover from e-commerce	Cloud	Robots	E-invoices	Share of workers with internet access	Share of workers with mobile device with internet	ICT training
2020 dummy	-0.053***	-0.034	-0.036**	0.000	-0.039	-0.039	-0.035	-0.014	-0.027	-0.035
	(0.017)	(0.027)	(0.017)	(0.000)	(0.026)	(0.026)	(0.027)	(0.025)	(0.020)	(0.038)
Digital variable	0.007**	-0.004	0.001	0.112	0.007	-0.031*	-0.008	0.024	-0.004	0.021*
	(0.003)	(0.012)	(0.018)	(0.069)	(0.014)	(0.016)	(0.022)	(0.024)	(0.031)	(0.012)
2020 dummy * digital variable[1]	0.006**	0.010	0.020	-0.072	0.002	0.002	0.056	-0.028	0.032	0.010
	(0.003)	(0.028)	(0.044)	(0.058)	(0.031)	(0.027)	(0.036)	(0.028)	(0.032)	(0.038)
Control variable										
Frontier growth	0.215***	0.228***	0.224***	0.240***	0.152***	0.153***	0.173***	0.229***	0.230***	0.229***
	(0.031)	(0.042)	(0.042)	(0.067)	(0.044)	(0.044)	(0.051)	(0.041)	(0.041)	(0.040)
Gap to the frontier (lagged)	0.249***	0.241***	0.243***	0.223***	0.242***	0.242***	0.223***	0.244***	0.244***	0.242***
	(0.037)	(0.056)	(0.056)	(0.054)	(0.048)	(0.047)	(0.057)	(0.054)	(0.056)	(0.054)
Capital per worker	0.009**	0.010*	0.010*	0.015**	0.012	0.012	0.013	0.010*	0.010*	0.010*
	(0.004)	(0.005)	(0.005)	(0.006)	(0.007)	(0.008)	(0.011)	(0.005)	(0.005)	(0.005)
Share of sales from exports	0.014	-0.042**	-0.039*	0.021	0.067***	0.072***	0.037	-0.040*	-0.039**	-0.039*
	(0.012)	(0.020)	(0.020)	(0.056)	(0.017)	(0.018)	(0.031)	(0.020)	(0.019)	(0.020)
Firm age	0.004	-0.003	-0.004	0.028	0.003	0.004	-0.015	-0.004	-0.003	-0.004
	(0.007)	(0.018)	(0.018)	(0.028)	(0.011)	(0.011)	(0.014)	(0.018)	(0.018)	(0.018)
Firm size (medium-sized enterprise)	0.000	-0.003	-0.007	0.015	0.003	0.006	0.018	-0.004	-0.003	-0.008
	(0.012)	(0.020)	(0.021)	(0.042)	(0.019)	(0.019)	(0.031)	(0.021)	(0.021)	(0.021)
Firm size (large enterprise)	-0.024	-0.015	-0.021	-0.033	-0.043*	-0.033	-0.022	-0.017	-0.017	-0.029
	(0.019)	(0.025)	(0.025)	(0.053)	(0.021)	(0.021)	(0.035)	(0.025)	(0.025)	(0.025)
Constant	-0.250***	-0.168***	-0.170***	-0.340*	-0.235**	-0.240***	-0.207	-0.181***	-0.174***	-0.175***
	(0.065)	(0.057)	(0.049)	(0.182)	(0.088)	(0.086)	(0.129)	(0.056)	(0.059)	(0.058)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3.018	1.043	1.034	175	1.082	1.082	689	1.043	1.043	1.043
R-squared	0.188	0.221	0.217	0.309	0.175	0.178	0.158	0.221	0.221	0.223

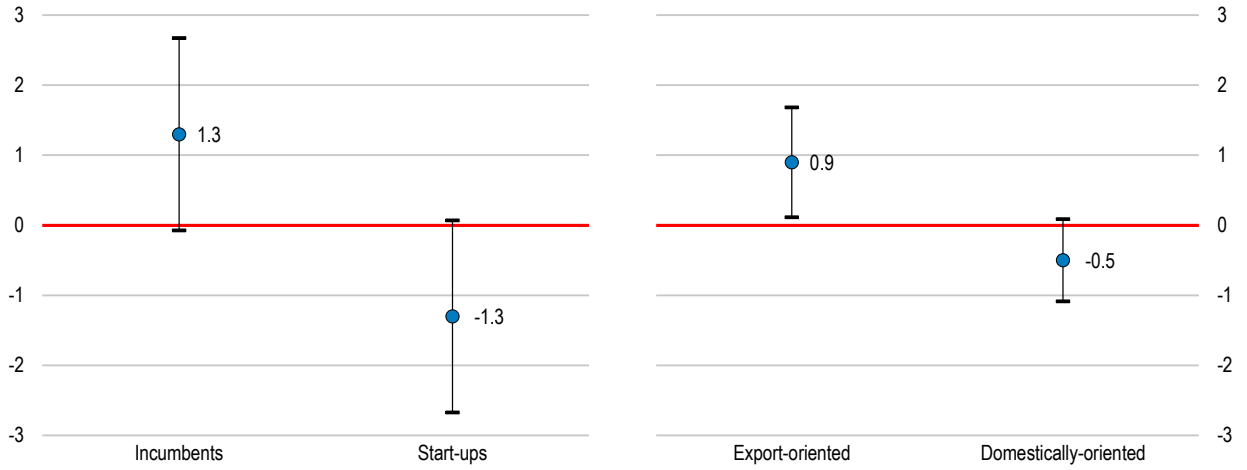
Note: [1] Digital variable denotes variables shown in the first row: ICT investment, broadband (>100Mbit/s), website for booking, turnover from e-commerce, cloud services, robots, e-invoices (in total invoices), share of workers with internet access for work purposes, share of workers with mobile device with internet access for work purposes (e.g., laptop, smartphone), and ICT training. Unreported results for social media, CRM and ERP front-office software are not significant.
The dependent variable is labour productivity growth. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Main results highlighted.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Export-oriented and incumbent firms benefit most from ICT investment

Figure 2 shows that the resilience effect of ICT investment on productivity growth in 2020 is stronger for incumbent firms than start-ups (firms established after the financial crisis) (see Figure C.1 in the Annex for full results). Moreover, export-oriented firms benefit more from ICT investment than domestically-oriented firms in terms of productivity resilience.

Figure 2. ICT investment effect on labour productivity growth by firm type

Annual effect on firm-level productivity growth from a 1% increase in ICT investment, percentage points



Note: Start-ups are defined as firms established in 2009 of after, while incumbent firms are established before 2009. An export-oriented firm generates 35% or more of its revenues with exports. Domestically-oriented firms generate less than 35% of their revenues with exports.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Labour reallocation dynamics

ICT-intensive firms benefit from labour reallocation but do not have stronger wage growth

Table 5 shows estimates from OLS regressions of firm-level employment growth on firm-level labour productivity and ICT investment between 2016 and 2020 (Column 1). The results show that labour productivity and ICT investment are positively and statistically significantly associated with employment growth. This suggests that labour reallocation benefits more productive and ICT intensive firms. In contrast, firm-level labour productivity is negatively and statistically significantly associated with wage growth, while ICT investment is not statistically associated with wage growth (Column 2).

Table 5. OLS regression results for employment and wage growth

DEPENDENT VARIABLE	Employment growth	Wage growth
Labour productivity	0.031***	-0.033***
	(0.007)	(0.009)
ICT investment	0.005***	0.000
	(0.001)	(0.001)
Capital per worker	0.006***	0.001
	(0.001)	(0.001)
Share of sales from exports	0.017	0.012***
	(0.014)	(0.003)
Firm age	-0.034***	-0.003
	(0.005)	(0.004)
Firm size (medium-sized enterprise)	-0.033***	0.002
	(0.007)	(0.003)
Firm size (large enterprise)	-0.058***	-0.006
	(0.006)	(0.007)
Manufacturing	0.062***	0.004
	(0.011)	(0.005)
Constant	-0.316***	0.349***
	(0.074)	(0.098)
Time fixed effects	Yes	Yes
Sector fixed effects	Yes	Yes
Observations	3.348	3.348
R-squared	0.108	0.037

Note: The dependent variable is employment growth (column 1) and wage growth (column 2). Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Main results highlighted.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Table 6 shows estimates from difference-in-difference regressions of firm-level employment growth in 2020 on firm-level ICT investment and digital adoption in 2019. Separate regressions were run for each digital variable (ICT investment, broadband, etc.). The coefficient on ICT investment in Column 1 is positive and statistically significant at the 1% level, suggesting that on average (within a sector), ICT-intensive firms had a 7.5 percentage point stronger employment growth than their less ICT-intensive peers in the course of 2020 when the pandemic hit the economy. Other variables capturing digital adoption in 2019 are not statistically significant, with the exception of the share of workers with mobile device (including laptops, tablets and smartphones) with internet access for work purposes. Finally, ICT investment does not lead to higher wage growth. Table 7 shows that ICT-intensive firms did on average not register stronger wage growth compared to less ICT-intensive firms, despite their higher productivity.

Table 6. Difference-in-difference regression results for employment growth

VARIABLES	ICT infrastructure		Digital solutions					ICT usage by workers and training		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	ICT invest-ment	Broad band (>100Mb/s)	Website for booking	Turnover from e-commerce	Cloud	Robots	E-invoices	Share of workers with internet access	Share of workers with mobile device with internet	ICT training
2020 dummy	0.000	-0.079***	0.000	-0.026	-0.030*	-0.018	-0.043***	-0.104***	-0.099***	-0.069***
	(0.000)	(0.021)	(0.000)	(0.017)	(0.017)	(0.016)	(0.015)	(0.023)	(0.016)	(0.011)
Digital variable	0.003	0.028*	-0.024	-0.036	0.009	0.024*	-0.006	0.032	0.087***	0.018
	(0.002)	(0.014)	(0.028)	(0.088)	(0.014)	(0.013)	(0.011)	(0.022)	(0.020)	(0.014)
2020 dummy * digital variable[1]	0.075***	0.005	0.024	0.090	-0.007	-0.047**	-0.020	0.052*	-0.118***	-0.011
	(0.018)	(0.020)	(0.029)	(0.060)	(0.019)	(0.017)	(0.020)	(0.029)	(0.031)	(0.016)
Control variables										
Labour productivity	0.018	-0.022	-0.023	0.042	0.033	0.036	0.052*	-0.020	-0.028	-0.023
	(0.013)	(0.020)	(0.022)	(0.046)	(0.029)	(0.028)	(0.030)	(0.021)	(0.022)	(0.022)
Capital per worker	0.005***	0.004**	0.005**	0.001	0.006*	0.006*	0.006**	0.006**	0.005**	0.005**
	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Share of sales from exports	0.028**	0.016	0.017	0.048	0.006	0.006	0.004	0.022	0.011	0.019
	(0.013)	(0.025)	(0.026)	(0.043)	(0.025)	(0.026)	(0.021)	(0.025)	(0.027)	(0.026)
Firm age	-0.014***	-0.013*	-0.011	-0.02	-0.019**	-0.019**	-0.012	-0.014	-0.013	-0.012
	(0.005)	(0.007)	(0.008)	(0.037)	(0.008)	(0.008)	(0.012)	(0.008)	(0.008)	(0.008)
Firm size (medium-sized enterprise)	-0.033***	-0.053***	-0.047***	-0.074***	-0.009	-0.009	0.013	-0.046***	-0.049***	-0.049***
	(0.007)	(0.014)	(0.014)	(0.016)	(0.013)	(0.013)	(0.016)	(0.013)	(0.013)	(0.014)
Firm size (large enterprise)	-0.067***	-0.073***	-0.062***	-0.094***	-0.056***	-0.056***	-0.053***	-0.065***	-0.064***	-0.071***
	(0.008)	(0.019)	(0.018)	(0.028)	(0.015)	(0.014)	(0.016)	(0.017)	(0.017)	(0.020)
Manufacturing	0.034***	0.077***	0.007	-0.002	-0.012	-0.017	0.054***	0.068***	0.03	0.041**
	(0.007)	(0.024)	(0.028)	(0.032)	(0.022)	(0.021)	(0.017)	(0.023)	(0.022)	(0.017)
Constant	-0.041*	0.011	-0.009	0.132	0.078*	0.086*	0.009	0.000	0.072**	0.032
	(0.020)	(0.020)	(0.037)	(0.133)	(0.043)	(0.044)	(0.040)	(0.027)	(0.031)	(0.028)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2.325	802	800	136	833	833	523	802	802	802
R-squared	0.131	0.185	0.177	0.407	0.134	0.141	0.223	0.183	0.198	0.177

Note: [1] Digital variable denotes variables shown in the first row: ICT investment, broadband (>100Mbit/s), website for booking, turnover from e-commerce, cloud services, robots, e-invoices (in total invoices), share of workers with internet access for work purposes, share of workers with mobile device with internet access for work purposes (e.g., laptop, smartphone), and ICT training. Unreported results for social media, CRM and ERP front-office software are not significant.
The dependent variable is employment growth. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Main results highlighted.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Table 7. Difference-in-difference regression results for wage growth

VARIABLES	ICT infrastructure		Digital solutions					ICT usage by workers and training		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	ICT invest-ment	Broad band (>100Mb/s)	Website for booking	Turnover from e-commerce	Cloud	Robots	E-invoices	Share of workers with internet access	Share of workers with mobile device with internet	ICT training
2020 dummy	0.000	0.026***	0.000	0.009	0.015	0.016	-0.005	0.042***	0.031***	0.008
	(0.000)	(0.008)	(0.000)	(0.022)	(0.012)	(0.011)	(0.009)	(0.013)	(0.009)	(0.011)
Digital variable	0.001	-0.006	0.012	0.117***	-0.004	-0.011	-0.012	-0.021	-0.046*	-0.007
	(0.001)	(0.008)	(0.008)	(0.023)	(0.008)	(0.007)	(0.012)	(0.015)	(0.023)	(0.010)
2020 dummy * digital variable[1]	-0.003**	-0.013	-0.022	-0.148**	0.011	0.013	0.050**	-0.043*	0.004	0.016
	(0.001)	(0.008)	(0.015)	(0.070)	(0.014)	(0.012)	(0.022)	(0.024)	(0.015)	(0.010)
Control variables										
Labour productivity	-0.020	0.000	-0.001	-0.042	-0.092	-0.092	-0.140	-0.001	0.002	-0.002
	(0.031)	(0.021)	(0.021)	(0.091)	(0.069)	(0.069)	(0.095)	(0.020)	(0.020)	(0.021)
Capital per worker	-0.001	-0.003*	-0.003	-0.001	0.000	0.000	0.002	-0.003*	-0.003	-0.003
	(0.001)	(0.002)	(0.002)	(0.003)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Share of sales from exports	0.002	-0.005	-0.005	-0.015	0.024**	0.025**	-0.001	-0.009	-0.006	-0.006
	(0.005)	(0.009)	(0.009)	(0.018)	(0.010)	(0.010)	(0.012)	(0.010)	(0.009)	(0.009)
Firm age	-0.003	0.001	0.001	0.018	-0.001	-0.001	0.003	0.002	0.001	0.001
	(0.004)	(0.006)	(0.007)	(0.033)	(0.006)	(0.006)	(0.009)	(0.007)	(0.007)	(0.007)
Firm size (medium-sized enterprise)	0.012***	0.006	0.004	-0.034**	0.008	0.008	-0.002	0.003	0.003	0.004
	(0.004)	(0.008)	(0.009)	(0.013)	(0.009)	(0.009)	(0.012)	(0.008)	(0.009)	(0.008)
Firm size (large enterprise)	0.016**	0.016	0.013	-0.007	0.003	0.005	-0.001	0.014	0.013	0.014
	(0.007)	(0.011)	(0.011)	(0.022)	(0.011)	(0.011)	(0.016)	(0.011)	(0.011)	(0.009)
Manufacturing	-0.037***	-0.071***	0.033***	0.092***	0.063***	0.065***	0.081**	-0.077***	-0.066***	-0.060***
	(0.010)	(0.012)	(0.011)	(0.032)	(0.017)	(0.016)	(0.032)	(0.012)	(0.010)	(0.013)
Constant	0.088***	0.129***	0.052*	-0.069	-0.046*	-0.051**	-0.095**	0.147***	0.125***	0.126***
	(0.013)	(0.019)	(0.028)	(0.122)	(0.024)	(0.024)	(0.036)	(0.021)	(0.019)	(0.021)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2.325	802	800	136	833	833	523	802	802	802
R-squared	0.027	0.075	0.074	0.243	0.106	0.107	0.175	0.084	0.077	0.073

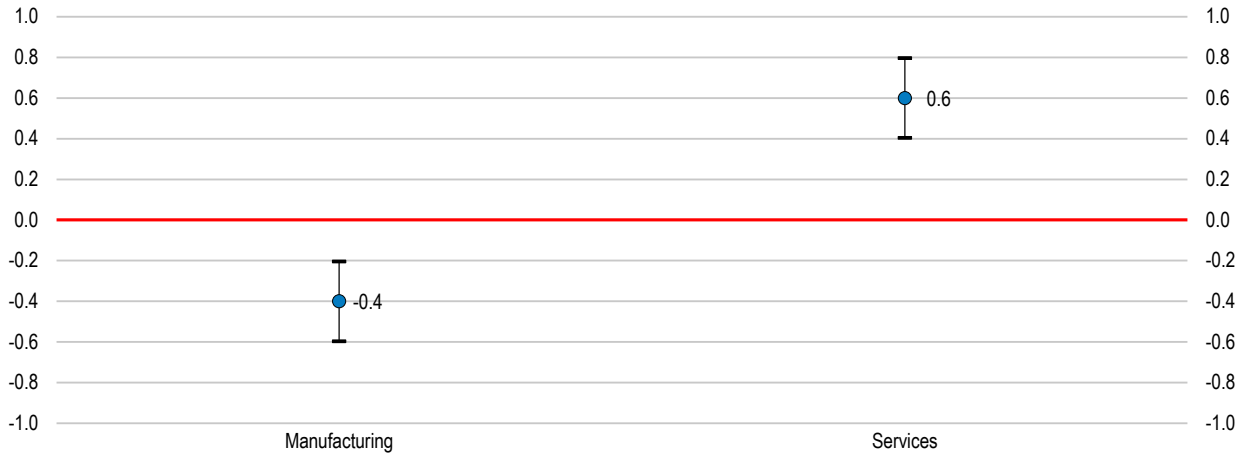
Note: [1] Digital variable denotes variables shown in the first row: ICT investment, broadband (>100Mbit/s), website for booking, turnover from e-commerce, cloud services, robots, e-invoices (in total invoices), share of workers with internet access for work purposes, share of workers with mobile device with internet access for work purposes (e.g., laptop, smartphone), and ICT training. Unreported results for social media, CRM and ERP front-office software are not significant.
The dependent variable is wage growth. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Main results highlighted.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Labour reallocation is stronger in the service sector

Figure 3 shows that employment growth stems primarily from firms that operate in the service sector (see Table C.2 in the Annex for full results). Firms that operate in the manufacturing sector recorded on average negative employment growth in 2020. Moreover, employment effects are positive and significant for domestically-oriented firms, while the effect is negative and significant for export-oriented firms. Results for start-ups and incumbent firms are not significant.

Figure 3. ICT investment effect on employment growth, manufacturing versus service sector

Annual effect on firm-level employment growth from a 1% increase in ICT investment, percentage points



Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Labour reallocation is lower in sectors with higher state-ownership

Finally, employment growth of privately-owned firms is in general negatively associated with the share of employment in state-owned (or partly state-owned) enterprises in a sector, as shown in Table 8. Moreover, the effect of ICT investment on private firms' employment growth in 2020 is weaker in sectors with a higher share of employment in state-owned (or partly state-owned) enterprises. The average share of employment in state-owned (or partly state-owned) enterprises in a sector is 12% with a standard deviation of 16%, implying that some sectors have considerably larger employment in state-owned enterprises (Table 2). For a one standard deviation increase in the sector-wide employment share in state-owned enterprises, employment growth decreases on average by 39 percentage points in privately-owned firms in the same sector.

Table 8. Difference-in-difference regression results for employment growth in private firms

DEPENDENT VARIABLE	Employment growth in private firms
ICT investment	0.039**
	(0.016)
Share of employment in SOEs	-0.392**
	(0.151)
2020 dummy * ICT investment * Share of employment in SOEs	-0.336***
	(0.097)

Control variables	
Labour productivity	0.031***
	(0.007)
Capital per worker	0.008***
	(0.002)
Share of sales from exports	0.019
	(0.013)
Firm age	-0.031***
	(0.005)
Firm size (medium-sized enterprise)	-0.032***
	(0.006)
Firm size (large enterprise)	-0.064***
	(0.007)
Constant	-0.232***
	(0.081)
Time fixed effects	Yes
Sector fixed effects	Yes
Observations	2.978
R-squared	0.145

Note: The dependent variable is employment growth in privately owned firms. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Main results highlighted.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Robustness checks

The results of the difference-in-difference estimation are robust to including sector-year fixed effects to control for time varying shocks that differ across sectors (Table C.3 in the Annex). However, a potential source of concern is that productivity and employment effects from ICT investment during the pandemic may capture the effects of other omitted variables. For instance, firms that were better managed before the pandemic may have improved their performance irrespective of their ICT investment (Bloom, Sadun and Reenen, 2012[13]). Nonetheless, Figure 1 above shows that ICT-intensive and less ICT-intensive firms displayed similar productivity and employment trends before the pandemic, with the exception of labour productivity growth in 2019. This suggest that productivity and employment growth differences between these two groups during the pandemic seem to be related to the nature of the COVID shock itself, which saw most on-site production affected. In contrast, firms that heavily invested in digitalisation were able to work themselves through this pandemic faster.

An important caveat is that the evidence provided on the resilience effect during the COVID-crisis may not be directly applicable to normal times as the pandemic was an unusual shock, both in terms of its nature and its size. Another caveat is that service sector firms and smaller enterprises with less than 50 employees are underrepresented in the sample. This results from the matching process of the various firm-level datasets, and especially from the underrepresentation of service sector and smaller firms in the investment and ICT surveys.

Several other limitations remain. First, the reported estimates may be a lower bound for the impact of ICT investment on productivity and employment. The analysis leaves aside possible effects of cross-sector reallocation and positive demand spillovers to other sectors. For instance, job losses in manufacturing could be offset by job creation in the service sector (Dauth et al., 2021[14]). Second, some endogeneity concerns remain. For instance, firms that had been better managed before the pandemic may have adopted more ICT and as a result performed better during the pandemic. Finally, the Business Registry only provides information on whether a firm is fully state-owned, partly state-owned or privately-owned. Information on the exact share the state holds is not available.

3. Summary and conclusions

This paper provides evidence on firm-level resilience and employment effects of digitalisation in Slovenia using the COVID-19 crisis as natural experiment. First, the findings point to a positive resilience effect for digitalised firms. Results show that on average within a sector, firms that were ICT-intensive before the pandemics managed to limit the decline in their annual labour productivity, while productivity of their less ICT-intensive peers fell to a stronger extent during the pandemic. The resilience effect is stronger for export-oriented firms than domestically-oriented firms, which may reflect a larger market to capitalise on the fixed costs of IT investment. Export-oriented firms are also well integrated into global value chains and benefit from international technology.

Second, COVID resulted in productivity-enhancing reallocation of labour to ICT-intensive firms. The pandemic affected overall employment negatively. Nevertheless, ICT-intensive firms registered 7.5 percentage point higher employment growth relative to their less ICT-intensive peers during the pandemic. The results account for the fact that some sectors were more heavily affected by the pandemic than others and that low-productivity firms may specialise in activities or sectors that are more difficult to digitalise.

However, the findings also point to factors that hamper the positive impacts of digitalisation. Specifically, investment in ICT does not lead to higher wage growth, despite higher productivity and digitalisation of ICT-intensive firms. This finding is in line with the low wage premium for IT professionals in Slovenia, which hampers reallocation of productive workers. This may reflect co-ordinated wage-setting at the sector level that ensures that workers receive similar wage increases within a very compressed wage structure. Such a process creates a disconnection between productivity and wages and reduces job mobility within a sector (OECD, 2022[15]). Moreover, high levels of state ownership in a sector reduce productivity-enhancing labour reallocation to privately-owned firms. This suggests that state-owned enterprises retain workers that could be redirected to more productive firms.

Together, these findings point to a positive effect of digitalisation on the resilience of firms to economic shocks. Despite the negative impact of the pandemic on overall productivity and employment, firms that had embraced digitalisation before the pandemic managed to work through it faster. On the other hand, less ICT-intensive firms saw a big contraction to their productivity and employment as the pandemic saw most on-site production affected. While these results confirm the importance of productivity-enhancing labour reallocation, they do not provide direct evidence on a positive firm-level productivity effect from digitalisation during normal times.

Looking beyond the pandemic, digitalisation has thus the potential to improve productivity of Slovenian enterprises, contributing to income convergence vis-à-vis richer OECD economies. It does so by strengthening the resilience of firms in face of disruptive change. This is an important cornerstone of long-term competitiveness as long as digital and productive firms have the necessary resources to thrive. Yet, labour market rigidities and state-ownership reduce overall positive impacts of digitalisation. This points to the importance of policy in supporting productivity growth. Policy can support productivity by continuing privatisations, thereby releasing labour for the benefit of more productive enterprises. Moreover, a more decentralised wage setting system can ensure a smooth reallocation of labour to productive enterprises that use digital solutions. Future research could focus on the effectiveness of regulatory and labour market policies in supporting productivity-enhancing reallocation, preferably in a cross-country perspective.

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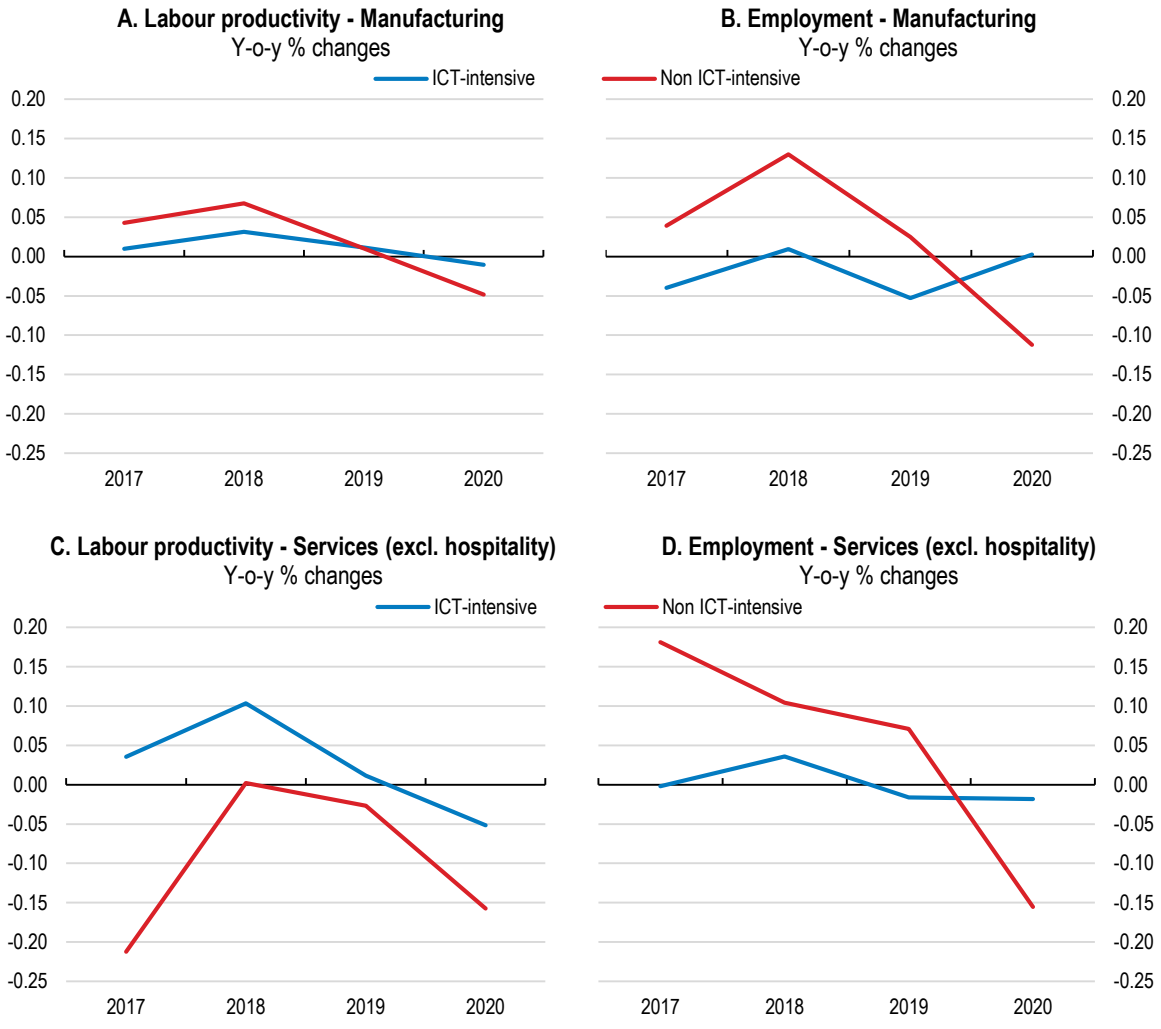
Annex. Additional regression results and robustness tests

Figure C.1. Productivity and employment growth by sector, ICT-intensive versus non-ICT-intensive firms



Note: ICT-intensive firms have an ICT investment share (in total investment) of 0.05% (median) or higher. In Panel C and D, 2-year moving averages were used.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Table C.1. Difference-in-difference regression results for productivity growth, by firm characteristics

FIRM CHARACTERISTIC	Privately-owned	State-owned or partly state-owned	Export-oriented	Domestically-oriented	Manufacturing	Services	Start-ups	Incumbents	Small	Medium
2020 dummy	-0.063**	-0.063**	-0.067**	-0.065**	-0.066**	0.000	-0.067**	-0.067**	-0.066**	-0.065**
	(0.028)	(0.028)	(0.029)	(0.029)	(0.029)	(0.000)	(0.030)	(0.030)	(0.029)	(0.029)
ICT investment	0.004*	0.004*	0.004	0.004	0.004*	0.005*	0.005*	0.005*	0.005*	0.005*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
2020 dummy * ICT investment	0.003	-0.004	0.009**	-0.005	0.003	0.001	-0.013*	0.013*	-0.003	0.003
	(0.008)	(0.008)	(0.004)	(0.003)	(0.004)	(0.003)	(0.007)	(0.007)	(0.004)	(0.004)
Control variables										
Frontier growth	0.223***	0.223***	0.223***	0.223***	0.224***	0.222***	0.225***	0.225***	0.229***	0.223***
	(0.031)	(0.031)	(0.031)	(0.031)	(0.032)	(0.031)	(0.030)	(0.030)	(0.032)	(0.031)
Gap to the frontier (lagged)	0.279***	0.279***	0.278***	0.278***	0.278***	0.278***	0.278***	0.278***	0.283***	0.279***
	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)	(0.037)	(0.038)
Capital per worker	0.012**	0.012**	0.012***	0.012**	0.012**	0.012**	0.012**	0.012**	0.012**	0.012**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Share of sales from exports	0.010	0.01	-0.021	0.024	0.01	0.011	0.011	0.011	0.007	0.01
	(0.014)	(0.014)	(0.018)	(0.016)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Firm age	0.003	0.003	0.002	0.002	0.002	0.002	-0.009	-0.009	0.002	0.002
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.011)	(0.011)	(0.007)	(0.007)
Firm size (medium-sized enterprise)	-0.003	-0.003	-0.005	-0.004	-0.004	-0.004	-0.004	-0.004	-1.380***	0.000
	(0.014)	(0.014)	(0.013)	(0.014)	(0.014)	(0.014)	(0.013)	(0.013)	(0.074)	(0.000)
Firm size (large enterprise)	-0.035	-0.035	-0.036*	-0.036*	-0.036*	-0.036*	-0.036*	-0.036*	-1.412***	-0.035*
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.077)	(0.021)
Constant	-0.292***	-0.278***	-0.268***	-0.285***	-0.435***	-0.274***	-0.241***	-0.250***	1.100***	-0.272***
	(0.073)	(0.069)	(0.068)	(0.068)	(0.070)	(0.068)	(0.083)	(0.074)	(0.074)	(0.069)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3.132	3.132	3.132	3.132	3.132	3.132	3.132	3.132	3.132	3.132
R-squared	0.206	0.206	0.208	0.206	0.205	0.205	0.208	0.208	0.212	0.205

Note: The dependent variable is labour productivity growth. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Main results highlighted.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Table C.2. Difference-in-difference regression results for employment growth, by firm characteristics

FIRM CHARACTERISTIC	Privately-owned	State-owned or partly state-owned	Export-oriented	Domestically-oriented	Manufacturing	Services	Start-ups	Incumbents	Small	Medium
2020 dummy	0.000	0.000	0.000	0.000	0.000	0.000	00.00	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ICT investment	0.003	0.003	0.003	0.003	0.003*	0.003*	0.003	0.003	0.003	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
2020 dummy * ICT investment	-0.003	0.003	-0.004**	0.004**	-0.004***	0.006***	-0.004*	0.004*	-0.002	0.003*
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)	(0.003)	(0.002)	(0.002)
Control variables										
Labour productivity	0.018	0.018	0.019	0.019	0.018	0.019	0.019	0.019	0.018	0.018
	(0.012)	(0.012)	(0.013)	(0.012)	(0.013)	(0.013)	(0.012)	(0.012)	(0.013)	(0.013)
Capital per worker	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Share of sales from exports	0.028**	0.028**	0.026	0.037*	0.028**	0.028**	0.028**	0.028**	0.028**	0.028**
	(0.013)	(0.013)	(0.018)	(0.018)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Firm age	-0.013***	-0.013***	-0.014***	-0.014***	-0.014***	-0.014***	-0.018**	-0.018**	-0.014***	-0.014***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.005)	(0.005)
Firm size (medium-sized enterprise)	-0.033***	-0.033***	-0.033***	-0.033***	-0.033***	-0.033***	-0.033***	-0.033***	0.034***	0.000
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.000)
Firm size (large enterprise)	-0.066***	-0.066***	-0.067***	-0.067***	-0.067***	-0.067***	-0.066***	-0.066***	0.000	-0.066***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.000)	(0.008)
Manufacturing	0.027***	0.028***	0.155***	0.025**	0.000	0.031***	0.021*	0.021*	0.031***	0.028***
	(0.009)	(0.009)	(0.010)	(0.011)	(0.000)	(0.007)	(0.011)	(0.011)	(0.009)	(0.008)
2020 dummy	0.000	0.000	0.000	0.000	0.000	0.000	00.00	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ICT investment	0.003	0.003	0.003	0.003	0.003*	0.003*	0.003	0.003	0.003	0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
2020 dummy * ICT investment	-0.003	0.003	-0.004**	0.004**	-0.004***	0.006***	-0.004*	0.004*	-0.002	0.003*
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)	(0.003)	(0.002)	(0.002)
Constant	-0.049**	-0.036*	-0.165***	-0.036*	-0.050**	-0.035*	-0.016	-0.019	-0.108***	-0.035*
	(0.021)	(0.021)	(0.022)	(0.020)	(0.020)	(0.020)	(0.027)	(0.023)	(0.024)	(0.020)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2.325	2.325	2.325	2.325	2.325	2.325	2.325	2.325	2.325	2.325
R-squared	0.131	0.131	0.132	0.133	0.133	0.134	0.132	0.132	0.131	0.132

Note: The dependent variable is employment growth. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Main results highlighted.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.

Table C.3. Difference-in-difference specification controlling for sector-year fixed effects

DEPENDENT VARIABLE	Labour productivity growth	Employment growth	Wage growth
2020 dummy	-0.457***	-0.056***	0.086***
	(0.050)	(0.011)	(0.010)
ICT investment	0.007**	0.003**	0.000
	(0.003)	(0.002)	(0.001)
2020 dummy * ICT investment	0.008**	0.001*	-0.002*
	(0.004)	0.000	(0.001)
	Control variables		
Capital per worker	0.009**	0.005***	-0.001
	(0.004)	(0.002)	(0.001)
Share of sales from exports	0.019	0.028**	0.002
	(0.013)	(0.013)	(0.005)
Firm age	0.002	-0.015***	-0.002
	(0.007)	(0.005)	(0.004)
Firm size (medium-sized enterprise)	-0.007	-0.033***	0.014***
	(0.013)	(0.007)	(0.004)
Firm size (large enterprise)	-0.033	-0.066***	0.016**
	(0.020)	(0.008)	(0.007)
Frontier growth	0.337**		
	(0.125)		
Gap to the frontier (lagged)	0.180***		
	(0.031)		
Labour productivity		0.012	-0.014
		(0.011)	(0.027)
Constant	-0.039	0.091***	0.065***
	(0.068)	(0.027)	(0.018)
Sector-year fixed effects	Yes	Yes	Yes
Observations	3.018	2.325	2.325
R-squared	0.206	0.169	0.078

Note: The dependent variable is labour productivity growth. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Main results highlighted.
Source: Authors' calculations based on administrative and business survey data from the Statistical Office of Slovenia.