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Adoption of digital and ICT technologies and firms' productivity

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Contents

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Abstract:
This paper has two main goals. First, it aims to answer the question on how the usage of ICT and digital technologies affects firm productivity. Second, it aims to analyze how change in the share of the manufacturing sector and/or the service sector in a given region direct changes in firm productivity. The analysis was carried out using a financial dataset of Croatian enterprises in the period from 2009 to 2019 and Eurostats' Digital Economy and Society data, based on "Community survey on ICT usage and ecommerce in enterprises". The data were analyzed using principal component analysis and panel data methods. The results indicate a positive relationship between adoption of ICT technologies and firm productivity, and a negative correlation between adoption of digital technologies and firm productivity. Furthermore, the results show a high degree of deindustrialization of certain regions and a positive correlation between industry intensity in certain regions and firm productivity. Finally, there seems to be a positive premium on productivity for larger-sized firms, firms participating in international trade, companies situated near to key international markets (i.e., located in counties bordering with the City of Zagreb).

Keywords: ICT, digital technologies, economy structure, productivity, Croatia
JEL classification: O14, O33

Usvajanje digitalnih i IKT tehnologija i produktivnost poduzeća

Sažetak:
Ovaj rad ima dva glavna cilja. Prvi cilj mu je odgovoriti na pitanje kako uporaba IKT i digitalnih tehnologija utječe na produktivnost poduzeća. Drugi cilj mu je analizirati kako promjene u udjelu proizvodnog sektora i/ili uslužnog sektora u određenoj regiji usmjeravaju promjene u produktivnosti poduzeća. Analiza je provedena pomoću financijskog skupa podataka hrvatskih poduzeća u razdoblju od 2009. do 2019. godine i Eurostatovih podataka o digitalnoj ekonomiji i društvu, na temelju „Ankete zajednice o korištenju IKT-a i e-trgovini u poduzećima". Podaci su analizirani metodom analize glavnih komponenata i metodama panel podataka. Rezultati ukazuju na pozitivnu vezu između usvajanja IKT tehnologija i produktivnosti poduzeća te na negativnu korelaciju između usvajanja digitalnih tehnologija i produktivnosti poduzeća. Nadalje, rezultati pokazuju visok stupanj deindustrijalizacije određenih regija i pozitivnu korelaciju između intenziteta industrije u određenim regijama s produktivnosti poduzeća. Konačno, rezultati ukazuju na pozitivnu premiju produktivnosti za veća poduzeća, poduzeća koja sudjeluju u međunarodnoj trgovini, te poduzeća smještena u blizini ključnih međunarodnih tržišta (tj. smještena u županijama koje graniče s Gradom Zagrebom).

Ključne riječi: IKT, digitalne tehnologije, ekonomska struktura, produktivnost, Hrvatska
JEL klasifikacija: O14, O33

1 Introduction

The Fourth Industrial Revolution can be considered as the creation of radical new technology using advanced information and communication technologies (ICT) and their implementation in more traditional and older parts of the techno-socio-economic realm, such as additive manufacturing (3D printing), the Internet of Things (IoT) and synthetic biology (Fagerberg and Verspagen, 2020). Industry is an important domain of technology use where industrial production systems are being transformed due to a higher level of digitalization, which leads to an intelligent, connected, and decentralized production. This new level of industry is called Industry 4.0 (Hermann, Pentek, and Otto 2016).

There are two groups of technologies which enable the current technological transformation on firm/sectoral level in national economies: (1) ICT technologies; and (2) technologies related to Industry 4.0 (we will refer to them as "digital technologies"). ICT technologies embody the characteristics of what Bresnahan and Trajtenberg (1995) call general-purpose technologies (GPTs): "characterized by pervasiveness, inherent potential for technical improvements and strengthen innovation complementarities, giving rise to increasing returns-to-scale", thus driving productivity growth. They can be considered as heterogenous technologies (DeStefano et al., 2018) and include information storage, processing, and communication. As for the technologies related to Industry 4.0, Zolas (2020) states that the following technologies belong to this group: artificial intelligence, cloud computing, robotics, and digitization of business information, whereas Gal (2019) includes in digital technologies broadband, enterprise resource planning (ERP), customer relationship management (CRM), and Cloud computing[1].

Diffusion of new technologies such as robotics, artificial intelligence, machine learning, and block chain also depend on regional performance of industries in the last several decades (Naudé et al., 2019). In the case of Central and Eastern European (CEE) countries, severe deindustrialization was observed during the 1990s, as well as signs of reindustrialization in some regions in the last decade (Stojčić et al., 2019). According to Bianchi and Labory (2018), the Fourth Industrial Revolution explains the process of deindustrialization with automatization of the production process and with "servitization" of manufacturing, where services (e.g., R&D activities and customer support services) create values in larger amount, compared with previous times.

The goals of this research are twofold. First, we investigate how the usage of ICT and digital technologies on a sectoral level affects firm productivity on individual firm basis. In terms of measuring technology adoption on sector level, we use several variables from

[1] We argue that these concepts are very similar in their terminology, where naming and classification into groups of technologies depend on applicability of technologies in national economies. In this research, we follow Gal's (2019) classification, because of existing available datasets.

Digital Economy and Society Statistics database by Eurostat. For measuring firm productivity and other firm characteristics, we use micro-level firm data obtained from the Croatian Financial Agency (FINA) for the 2009-2019 period, including balance sheet and profit and loss statement data, as well as firm characteristics such as region, size, industry sector, firm ID and year of the report, covering more than 300 variables for the universe of Croatian incorporated firms. The second goal is to analyze how structure of a specific region (composition of industry and services in terms of employment and value added) is affecting the firms' productivity in the past decade. The change in regional economy structure is analyzed by the degree of deindustrialization and/or reindustrialization. The former term is used to describe a situation where there is a decline in the share of industry employment and/or share of industry value added in total employment and/or output of a given region. The opposite is true for the latter term. For this analysis, share of reduction/increase of employment in industry sector in relation to the total number of employees is analyzed[2]. Due to a large time span and information on universe of Croatian firms, panel data estimation techniques are utilized in the analysis.

The analysis presented in this research is a novelty in several ways. First, our research analyzes productivity as the result of use of ICT and digital technologies together at the sector level in Croatia. Most of the existing literature about the relation between usage/adoption of various technologies and productivity analyzes these technology groups separately, analyzing only the specific technology and its economic effects at the firm level (EC, 2020; Deloitte, 2020). Second, our analysis covers a longer period of the last decade. Thus, it includes both the effects of the global financial crisis that started at the end of 2008 and the recession that ensued afterwards from 2009 to 2014, as well as the recovery period from 2015 to 2019. Moving on, the level of aggregation used in the analysis is an important issue which may explain the relation between technology and productivity. Thus, the final novelty of our research is the usage of multilevel analysis on how the regional structure of the economy (counties and NUTS 2 regions) in combination with the mentioned sectoral adoption of different technologies affects individual firms' productivity. Zolas et al. (2020) point out that scarcity of firm level data was considered as the central bottleneck in developing and better understanding of the effects of these technologies on productivity. Referring to DeStefano, Kneller and Timmis (2014) and Syverson (2011), Gal et al. (2019) argue that both the firm level and the industry level of the analyses have advantages and downsides. Firm-level analyses are typically more subject to endogeneity issues, although firm-level studies can miss the positive spillovers generated by adoption by other firms. On the other side, industry-level studies include both within-firm and spillover effects (typically without being able to make a distinction), but they do not analyze the firm-level heterogeneity in productivity drivers and performance. To address this problem,

[2] This approach is identical to the left side of Tregenna (2011) formula, where the right side of the formula includes an explanation of deindustrialization: changes in labour intensity, sectoral competitiveness and overall productivity on the county level.

our study combines both sectoral-level data on technology adoption, regional-level data on the economy structure, and firm-level data on productivity. Results of this multilevel analysis can serve as an analytical basis for strategies and/or programs aimed at further development of innovation policy and industrial policy in the context of the Fourth Industrial Revolution.

2 Theoretical background and hypotheses

2.1 The intertwining technologies and productivity

Current technological transformation is marked with intertwining between digitized advanced technologies related to Industry 4.0 (e.g., Cloud computing, robotics) and the ICT technologies. This results in the unified use of these technologies (c.f. Gerrikagoitia et al., 2019) at the firm level, among households, and in institutions. The empirical analyses can be conducted in two ways, analyzing the various investments in a specific digital technology (e.g., Bessen and Righi, 2020) or analyzing the use and/or adoption of the specific digital technology (e.g., Dinlersoz and Wolf, 2018). Also, the empirical analyses can include a combination of technology usage/adoption with other factors such as R&D and intangible investments (Mohnen, Polder and Van Leeuwen, 2018), organizational capital and management skills (Brynjolfsson and Hitt, 2000), human capital and ICT related skills (Bugamelli and Pagano, 2004). It is easy to understand that indicators related to the use of technologies[3] in the process of technological transformation can be divided into three groups: (1) indicators related to the inputs of technological transformation[4], (2) indicators related to technological transformation process[5], and (3) indicators related to the output of technological transformation[6]. All these indicators, measured at either firm or sectoral level, differently affect an individual firm's productivity. The increased availability of data and their transformation into economically meaningful knowledge, which can be used for design and production decisions, open new opportunities for organizing manufacturing in value chains (De Backer and Flaig, 2017).

The empirical results of the analyses about the relation between the use of various advanced technologies and productivity are complex (c.f. Gal et al., 2019). There are studies which provide evidence on positive links between investments in digital technologies and productivity on both the firm and industry level (e.g., Munch et al., 2018; Gal et al., 2019). Acemoglu et al. (2020) find that diffusion of robots has had important labour

[3] Such as the indicators related to innovation activities in CDM model (Crepon et al., 1998).

[4] For example, indicators related to Internet access and/or indicators which describe and employ expert knowledge.

[5] For example, indicators which describe transformation of inputs related to the use of technologies into outputs related to the use of technologies.

[6] For example, indicators related to online sales and/or indicators that describe enterprises' total turnover.

market and productivity consequences across regions. On the other side, some studies report no effect of IT intensity on manufacturing productivity (Acemoglu et al., 2014)[7]. That corresponds to Bartelsman et al. (2017), who found no significant effect of broadband access on within-firm productivity, but still a positive effect at the aggregate level. In recent literature dealing with the use of advanced technology related to Industry 4.0, the prevailing opinion is that the mass use of digital information is the necessary input to more-advanced uses of digital technologies (Zolas et al., 2020: 5, reciting Brynjolfsson and McElheran, 2019).

When it comes to the relation between the concepts of ICT technologies and productivity, it has changed over time. Traditionally, ICT is modelled as an aggregated, homogenous capital. In terms of the analysis, IT investment in computers and data processing equipment and various categories related to expenses related to IT[8] are important. As mentioned earlier, in the last decade, heterogenous types of ICT technologies have been recognized. DeStefano et al. (2018) state that these new types of technologies provide firms with a variety of ways to store, process and transmit information, which in turn generates new knowledge and improves coordination and communication across production lines and with customers. This implies the emergence of analytical categories of the analyses related to the adoption and use of technologies, i.e., analytical categories which explain massive use of digital information.

Based on these findings, we make the following hypothesis:

Hypothesis 1. Higher adoption rates of different technologies have positive effects on firm productivity.

2.2 Adoption rate of the technologies and productivity

The multidimensional concept of technological transformations related to Industry 4.0 implies complex effects on the environments they operate in. Thus, it is crucial to determine at which point the technology is analyzed, i.e., is it at the beginning of use/application, in the period of its diffusion (accepted as a common standard) or in the period when it becomes mature (c.f. Corrocher and Ordanini, 2002). This is tightly connected to the countries' engagement within the production of technologies related to the technological revolution[9]. The main distinction among the countries relates to whether

[7] Within this study computer-producing industry was an exception.

[8] These are expenses related to hardware and equipment, purchased software, data and other purchased computer services.

[9] Technological revolutions are not to be confused with industrial revolutions. A technological revolution (Perez, 2003, 2010) refers more to the notion of the use of technology as opposed to an industrial revolution where the emphasis is on the organization of industries (Bianchi and Labory, 2018).

a country is considered as a frontrunner or as a follower in the production or in the use of emerging technologies. In the former case, i.e., if a country creates technologies, it is more likely that there are important groups of firms capable to use digital technologies related to Industry 4.0. Otherwise, if a country is a follower in the use of emerging technologies (Croatia belongs to this group), the emphasis in these national economies is on the use of standardized technologies that made up the previous stage of the current industrial revolutions, such as ICT technologies. According to the criteria of inventing and using Advanced Developed Production (ADP) technologies of the Fourth Industrial Revolution, the United Nations Industrial Development Organization (UNIDO) grouped the national economies in the following groups: frontrunners, followers, latecomers and laggards (UNIDO, 2020). Since Croatia belongs to the group of follower countries[10] according to the level of engagement within ADP technologies applied in manufacturing, it is to be expected that application of advanced developed production related to the Fourth Industrial Revolution is at the initial stage, so the emphasis in these national economies at the moment is on the use of technologies that made up previous technological and industrial revolutions, i.e., ICT technologies. Analyzing readiness of Industry 4.0 with indicators for technological, entrepreneurial and governance competences, Naude et al. (2019) found that the Czech Republic, Lithuania, Hungary, and Slovenia are the readiest for Industry 4.0 among the CEE countries, followed by Poland, Slovakia, Croatia, Bulgaria, and Romania. Therefore, we hypothesize that ICT technologies will be more connected to the productivity of individual firms than digital technologies:

Hypothesis 2. Adoption rates of ICT technologies have greater effect on firm productivity than adoption rates of digital technologies in Croatia.

2.3 Structure of the economy and diffusion of technology

Finally, regarding the effect of the economy structure on firm productivity, it is easy to understand that the effects of different technologies on firm productivity are connected to the structure of economies that these firms operate in (the share of the manufacturing sector and/or the service sector in national economies). The structure of the economy directs specific technology and intensity of its application[11]. Also, productivity gains tend to materialize with a certain lag, as digital adoption can disrupt production processes in the short term and require organizational adjustments to fulfil their potential (Brynjolfsson, Rock and Syverson, 2017).

[10] Croatia belongs to the subcategory of producers (of technology) within the category of followers. According to the Competitive Industrial Performance index, it ranked 45th. This composite index was made using the following dimensions: capacity to produce and export manufactures, technological deepening and upgrading, and world impact. For more information about the dimensions of index, please see UNIDO (2020: 155).

[11] It is obvious that in a country where tourism is an important business sector, such as Croatia, companies in this sector are among the most frequent users of online orders compared to companies in the other sectors.

Regarding this, it is important to know that in national economies, regardless of their level of development, there are different structures of the sectors within their region at the NUTS 2 level. As the structure of these regions changes over time, they may experience an increase or decrease in the share of employees or valued added in their industry sectors[12]. On the other side, the current technological transformation may itself change the regional structure of the economy. This argument is primarily related to characteristics of investments in the technologies. In the current technological transformation related to Industry 4.0, investments in intangible assets (such as investments in data, software, market analysis, organizational design, patents, copyrights, etc.) become more relevant compared to investments in physical assets. Digital technologies fall into this group of intangible assets and the activities related to digital technologies are mostly considered as services (Mayer, 2018). This means that, in a digital world, services increasingly permeate the goods sector and blur the traditional boundaries between goods and services in the manufacturing process, thus decreasing the overall industry share of a given region. Analyzing the determinants of the structural (between-sectoral) and productive (within-sectoral) transformation[13] of 56 NUTS 2 regions in Central and East European countries over the 2008–2014 period, Stojčić et al. (2019) found that equal access to digital infrastructure in urban and rural areas and transfer of skills and knowledge through the inflow of foreign investment and imports of production inputs increase the contribution of manufacturing to regional employment in these areas. This finding must be understood in the context of Nubler's (2014) statement about the components of catching-up and growth mechanism, stating that both concepts are determined not only by the accumulation of production factors and the changing factor endowment structure, but also by the transformation of a country's specific productive capabilities embedded in the society. Taking this into account, we hypothesize:

Hypothesis 3. The industry share in each region positively affects firm productivity.

3 Data and methodology

3.1 Data

Two datasets were merged: (1) financial and structural data on the population of the Croatian enterprises for the 2009–2019 period, obtained from the Croatian Financial Agency (hereinafter: FINA); and (2) data on the adoption of digital technologies in the

[12] In case of increased share of the number of employees in the total number of employees, it is considered that the region experienced a deindustrialisation, whereas in the case of decreased share of the number of employees in the total number of employees, it is considered that the region experienced a re-industrialisation.

[13] Nubler (2014) states that productive transformation embraces both technological change and diversification into new economic activities and sectors.

2009–2019 period, obtained from Eurostats' Digital Economy and Society data, based on "Community survey on ICT usage and ecommerce in enterprises" (hereinafter: DES).

The FINA dataset includes balance sheet and profit and loss statement data covering 300 variables for the universe of the Croatian incorporated firms, as well as firm characteristics such as region, size, industry sector, firm ID and year of the report. On the other hand, the DES dataset has country and industry dimensions and, for a subsample of technologies, also a time dimension. The survey provides a compilation of data on the use of various types of information and communication technologies in enterprises.

After merging the FINA and DES datasets, available data includes 166,059 firms, on which we start our data cleaning process. Due to restrictions of the DES dataset, our analysis is limited to NACE 1-digit sectors C, D, E, F, G, H, I, J, K, L, M and N. We remove all firms from financial and insurance sector (NACE 1-digit sector K) as their operations are quite specific and not suitable for our analysis. This marginally reduces our dataset to 165,448 firms. We also only keep firms in private ownership and exclude firms having either no employees or zero turnover (as those firms cannot be considered as "healthy firms"), further reducing our sample to 57,047 firms, which is our final sample. If we include a time dimension, we have overall 348,456 observations (on average we have 6 observations per firm).

3.2 Method

Our empirical estimation takes the production-function approach which is amended with technology diffusion variables and variables measuring the share of industry employment of a certain region. We are utilizing both pooled OLS and firm-specific panel data models for estimations.

Our model is the following:

$$TFP_{iscrt} = \alpha + \beta_1 ICT_{st} + \beta_2 DIGTECH_{st} + \beta_3 SHINDEMP_{ct} + \gamma X_{iscrt} + \delta_s + \theta_c + \lambda_r + \phi_t + \chi_i + \varepsilon_{isct} \quad (1)$$

where TFP_{iscrt} denotes total factor productivity of firm i operating in sector s located in county c in region r in year t; ICT_{st} and $DIGTECH_{st}$ are variables which capture the firms' technological capacity (extracted from Eurostat data) in sector s (NACE 2-digit) in year t; $SHINDEMP_{ct}$ is an industry share of employment in total employment in county c in t (used to approximate the effect of reindustrialization or deindustrialization over the observed period); and X_{iscrt} is a martix of other firm time-variant characteristics including the firms' age, intangible assets, average wage, debt ratio, size and their trade orientation. δ_s captures time-invariant technological-sector specific effects, θ_c captures county time-invariant specific effects, λ_r captures region time-invariant specific effects, ϕ_t captures period-specific effects[14] and χ_i captures time-invariant firm-specific effects[15]. It is important to note that digital development data is only available on the sector (NACE 2-digit) level, while data on industry share of employment is calculated on the county level. Time period of our analysis is from 2009 to 2019, due to data availability on firms' technological usage from Eurostat.

3.3 Description of variables used in the analysis

The dependent variable in our model is the total factor productivity (TFP), which was estimated using Wooldridge's (2009) methodology based on the production function approach, using value-added as output, labor and capital as inputs, and intermediate inputs to control for unobservables. As technologies used in the production process differ across different industries, TFP was estimated separately for each NACE 2-digit sector.

The first set of covariates comes from the DES dataset. Regarding the use of this dataset, our analysis focuses on a subset of indicators presented in Table 1, selected from a list of several hundred available variables. These indicators were selected based on their potential to improve within-firm productivity, as well as having spillovers on other firms (e.g., ERP) and potential complementarities among themselves (e.g., broadband internet access with other technologies). An additional selection criterion was to maximize cross-industry coverage for Croatia. Since adoption rates of different technologies are highly correlated (Table 3) and there could be complementarities from adopting them jointly, we combine them into two different indices using their first two principal components (i.e., the linear combination of adoption rates that accounts for the largest fraction of their total variance) based on the criteria of eigenvalue greater than one. Together, the first two principal components explain a high fraction of the overall variation in the digital adoption indicators, and the weights assigned to them are relatively close to each other, implying that all technologies are important contributors to their principal components (Table 4). The digital adoption variables that are heavily loading on the first component are all connected to the ICT components (e_cuse, e_iacc, e_webacc, e_awsval, e_axsval, e_eturn, e_ecom, e_web, e_webot, e_webper, e_esell, e_iuse_gt50, e_webord, e_webvac), so that this first component was labeled as the ICT index. On the other hand, digital adoption variables that are heavily loading on the second component are all connected to digital technology

[14] We have defined two periods across our analyzed period 2009-2019, based on the trajectory of the Croatian economy. The first period ranges from 2009 to2014 and corresponds to the time of recession, while the second period ranges from 2015 to 2019 and corresponds to the time of the expansion of the Croatian economy.

[15] This is used only with panel data fixed effects estimator without using other time-invariant firm characteristics.

components (e_crmstr, e_webctm, e_itsp2_or_rcr2, e_erp1, e_ispdf_ge30, e_sisc, e_cc, e_siscall), so that this second component was labeled as the DIGTECH index[16]. More broadly, these indices may capture a general tendency of digital technology diffusion in each industry over the analyzed period, in which case it is possible that it captures, to some extent, the adoption of other digital technologies not covered in this paper[17]. Kaiser-Meyer-Olkin sampling adequacy measure of 0.76 justifies the usage of principal component analysis.

Our second set of covariates includes a share of industry employment in total employment in each county, which, over a certain period, approximates the rate of deindustrialization or reindustrialization. This was defined using Tregenna's (2011) methodology[18]:

$$SHINDEMP_{ct} = \frac{L\_IND_{ct}}{L_{ct}} \tag{2}$$

where $SHINDEMP_{ct}$ denotes a share of the industry employment (L_IND_{ct}) in county c in year t with regards to total employment in county c in year t (L_{ct}). Industry in each county is defined as union of the following NACE 1-digit sectors: C-Manufacturing; D-Electricity, gas; and E-Water supply.

As other covariates, we select relevant firm characteristics that impact the outcome, i.e., their productivity level. Firm age is included to capture the effect of "newly established firms" that might show an increased volatility of their productivity within the first few years on the market. Firm size (classified based on the number of employees) is included to capture the effect of the volume of the firms' employees, capital, and different synergy effect in larger firms. Average wage is included to proxy for firm financial stability and their human capital. Firms that pay higher average wages have on average larger capital and cash reserves and are, thus, more likely to be financially stronger. Higher average wages may also reflect higher competence and education level of the firms' workforce. Furthermore, firms that hold some knowledge-related capabilities indicated by ownership of fixed intangible assets may facilitate more sophisticated production processes, which lead to higher outputs. Firms that are exporters tend to be more productive (Costa, Pappalardo, and Vicarelli, 2017) and have specific entrepreneurial skills and human capital (Brambilla, Ledernam, and Porto, 2012) that can affect their productivity. Therefore, we use a set of dummies to

[16] This digital technology index includes components which can be described as additional use of the ICT, as these components can be considered as more compatible with the technologies related to Industry 4.0 (e.g., robotics) in comparison with the core ICT index.

[17] Community survey on ICT usage and ecommerce in enterprises includes variables related to Cloud computing and various aspects of Big data use, but unfortunately there are a lot of missing values among these variables, which limits the use of additional variables (more closely related to technologies of Industry 4.0) in the model (Table 2).

[18] We only use the left part, i.e., the dependent variable of this equation.

control for the firms' trade orientation. All variables used in this research are described in Table 1.

Table 1 **Variables used in the analysis**	
Variable	**Description**
Firm characteristics (source: FINA)	
Age	Age of the firm
Age_sq	Squared age of the firm
Tech_intensity	Sectors of economy based on technological intensity*: 1 – High-tech manufacturing, 2 – Mid high-tech manufacturing, 3 – Mid low-tech manufacturing, 4 – Low-tech manufacturing, 5 – Knowledge-intensive market services, 6 – Knowledge-intensive high-tech services, 7 – Knowledge-intensive other services, 8 – Less knowledge-intensive market services, 9 – Less knowledge-intensive other services
Region	Croatian NUTS2 regions** classified as: 1 – Panonian Croatia, 2 – Adriatic Croatia, 3 – the City of Zagreb, 4 – North Croatia
Size	Size of the firm: 1 – Micro (1–9 employees), 2 – Small (10–49 employees), 3 – Medium (50–249 employees), 4 – Large (250 or more employees)
Trade	Trade orientation of the firm: 1 – Exporter only, 2 – Importer only, 3 – Exporter and importer, 4 – Domestic market only
*Firm performance characteristics*** (source: FINA)*	
Labor	ln(1 + number of employees)
Average_wage	ln(1 + real average personnel costs)
Capital	ln(1 + real tangible fixed assets)
Fixed_intangible_assets	ln(1 + real intangible fixed assets)
Turnover	ln(1 + real turnover)
Rva	ln(1 + real value-added)
Tfp	ln(total factor productivity)
*Digital technologies adoption**** (source: DES)*	
e_cuse	Percentage of enterprises using computers
e_iacc	Percentage of enterprises with internet access
e_webacc	Percentage of enterprises where the website provided description of goods or services, price lists
e_awsval	Enterprises' turnover from web sales
e_axsval	Enterprises' turnover from EDI-type sales
e_eturn	Enterprises' total turnover from e-commerce
e_ecom	Percentage of enterprises having sent or received orders via any computer networks
e_web	Percentage of enterprises with a website
e_webot	Percentage of enterprises with a website that provided order tracking available online
e_webper	Percentage of enterprises with websites that have personalized content for regular/recurrent visitors
e_esell	Percentage of enterprises selling online (at least 1% of turnover)
e_iuse_gt50	Percentage of enterprises where more than 50% of employees used computers with access to the internet for business purposes
e_webord	Percentage of enterprises with the website that provided online ordering, reservation or booking, e.g., shopping cart
e_webvac	Percentage of enterprises with the website that provided advertisements for open job positions or online job applications
e_crmstr	Percentage of enterprises using Customer Relationship Management to capture, store and make available clients' information to other business functions

e_webctm	Percentage of enterprises with the website that enables visitors to customize or design online goods or services
e_itsp2_or_rcr2	Percentage of enterprises which employ ICT specialists or have recruited/tried to recruit ICT specialists
e_erp1	Percentage of enterprises which have ERP software package to share information between different functional areas
e_ispdf_ge30	Percentage of enterprises where the maximum contracted download speed of the fastest internet connection is at least 30 Mb/s
e_sisc	Percentage of enterprises where business processes are automatically linked to those of their suppliers and/or customers
e_cc	Percentage of enterprises which buy cloud computing services used over the internet
e_siscall	Percentage of enterprises which share SCM information via electronic transmission suitable for automated processing and via websites

*Notes: *Definitions of these technology sectors are available at https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf. **According to NUTS 2021 classification, available at https://ec.europa.eu/eurostat/web/nuts/background. ***All monetary variables were deflated using year- and sector- (NACE 2-digit) specific Eurostat deflators with base in 2010. Value-added was deflated using value-added deflator. Intermediate inputs (raw materials and energy) were deflated using intermediate input deflator. All other monetary variables were deflated using output deflators. ****DES data variables are expressed as a percentage of firms in each NACE 2-digit industry. These variables are used in principal component analysis to construct ICT and DIGTECH indices.*

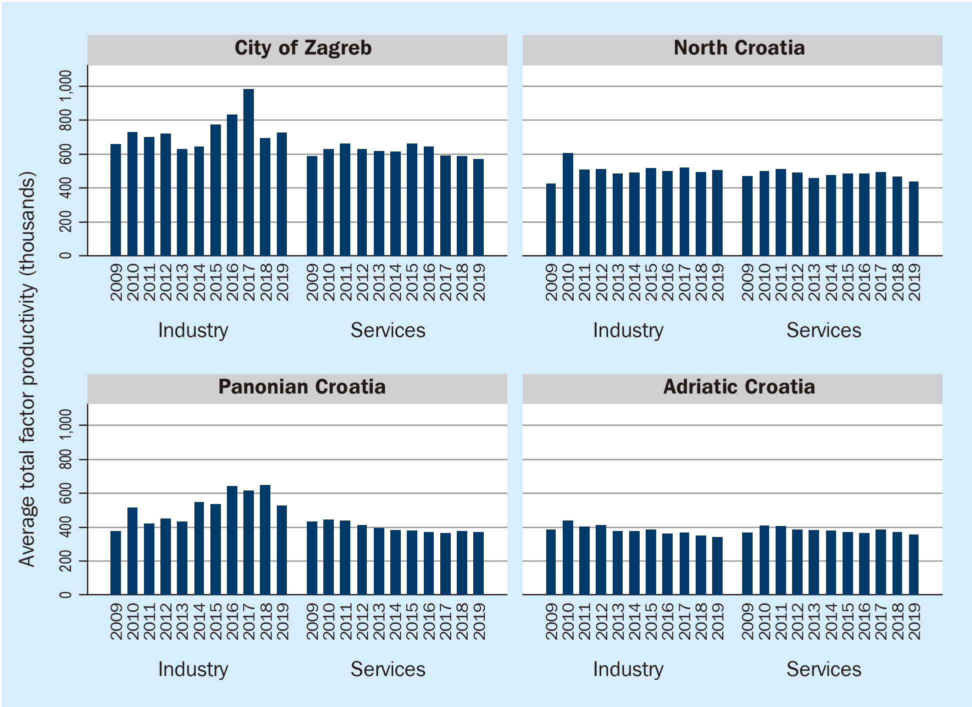
4 Results

4.1 Descriptive statistics

4.1.1 TFP distribution

TFP distribution across different Croatian NUTS 2 regions and sectors is presented in Figure 1. It is no surprise that the Zagreb region is showing the highest average TFP figures across the observed period, given that this is the capital of Croatia. What can also be noticed is that average TFP figures were on the rise until 2011, even though the Croatian economy was severely hit by the financial crisis in late 2008. After reaching its peak in 2011, average TFP started to decline and bottom out in 2013, after which it has again been increasing with the overall economic recovery. This trend is very similar in other Croatian regions, although at a lower average TFP levels and somewhat less pronounced. Overall, the lowest TFP levels are found in Adriatic Croatia, which is mostly concentrated on tourism and service-related activities. In terms of TFP distribution across sectors, Zagreb and Panonian Croatia regions have higher TFP values in industry compared to services, while in North and Adriatic Croatia TFP differences across these sectors are less pronounced. These trends are also corroborated by very similar trends in labor productivity, presented in Figure 6 in the Appendix. Thus, we expect the highest TFP premium of firms located in the Zagreb region.

Figure 1 **TFP distribution across different Croatian NUTS 2 regions and sectors over time**



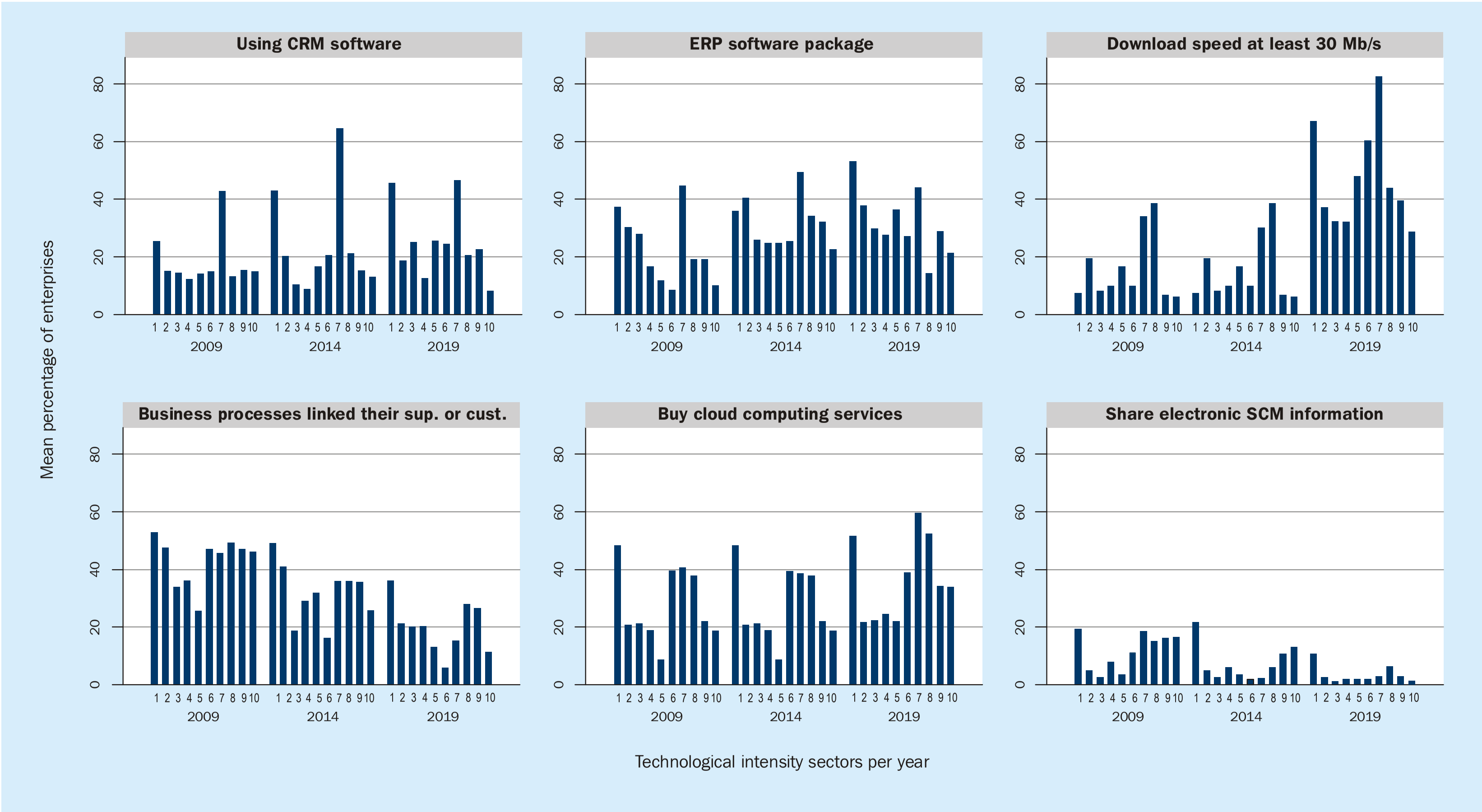
Notes: Regions are defined according to NUTS 2021 classification, available at https://ec.europa.eu/eurostat/web/nuts/background. Industry is defined as NACE 1-digit sectors C, D and E. Services are defined as NACE 1-digit sectors G, H, I, J, L, M and N.

Source: Authors' calculations based on the FINA database.

4.1.2 Adoption of digital technologies

The adoption of digital technologies varies significantly across industries with different technological intensity and is generally higher in services than in manufacturing. Figure 2 shows the average adoption rates of selected digital technologies in three selected years in our analyzed period (2009, 2014 and 2019) across a range of analyzed technological intensity sectors. The greatest difference across all sectors is observed in the availability of high-speed internet, proxied by the availability of download speed of at least 30 MB/s, which recorded an increase in all sectors, most notably in sectors where the usage of information and communication technologies is the highest (market and high-tech knowledge-intensive services, and high-tech manufacturing). ERP usage also recorded a moderate increase across all industries, albeit at a rate lower than the available download speed. It also seems to be higher in manufacturing than in services. Percentage of enterprises which use CRM software and buy cloud computing services remained relatively stable in the observed period, again with high-tech manufacturing and high-tech knowledge-intensive service sectors recording the highest share. Description of adoption of ICT technologies is presented in Figure 7 in the Appendix.

Figure 2 **The diffusion of digital technologies across sectors and time**

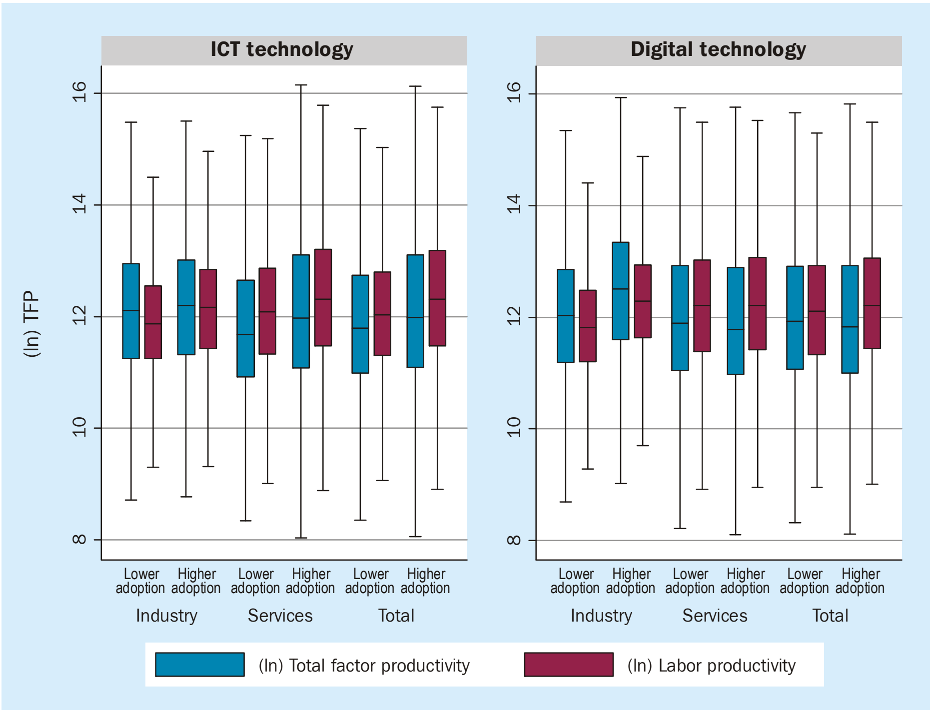


Notes: This figure shows the average adoption rate of selected digital technologies in three selected years in the following technological sectors: 1 – High-tech manufacturing; 2 – Medium high-tech manufacturing; 3 – Medium low-tech manufacturing; 4 – Low-tech manufacturing; 5 – Energy; 6 – Market knowledge-intensive services; 7 – High-tech knowledge-intensive services; 8 – Other knowledge-intensive services; 9 – Market less knowledge-intensive services; 10 – Other less knowledge-intensive services. Definitions of these sectors are available at https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf. CRM stands for "Customer Relationship Management", ERP for "Enterprise Resource Planning", and SCM for "Supply Chain Management".

Source: Authors' calculations based on Eurostat's comprehensive database, Digital Economy and Society Statistics.

A simple box-plot diagram (Figure 3) suggests that firms tend to have higher productivity when they operate in industries where adoption rates of both ICT and digital technologies are higher. Differences seem to be more pronounced for ICT technology adoption than for digital technologies adoption in services, and vice versa in industry. Overall, differences are much more pronounced for adoption of ICT technologies. This means that more frequent use of ICT technologies is present among companies within leading sectors in terms of TFP in Croatia. As a corroboration of this trend, we have also added labor productivity on the graph which shows a similar trend.

Figure 3 **TFP distribution across different rates of technology adoption and sectors**



Notes: "Higher adoption" and "lower adoption" denote firms that are above and below the median technology adoption rates in ICT technology index and digital technology index respectively.

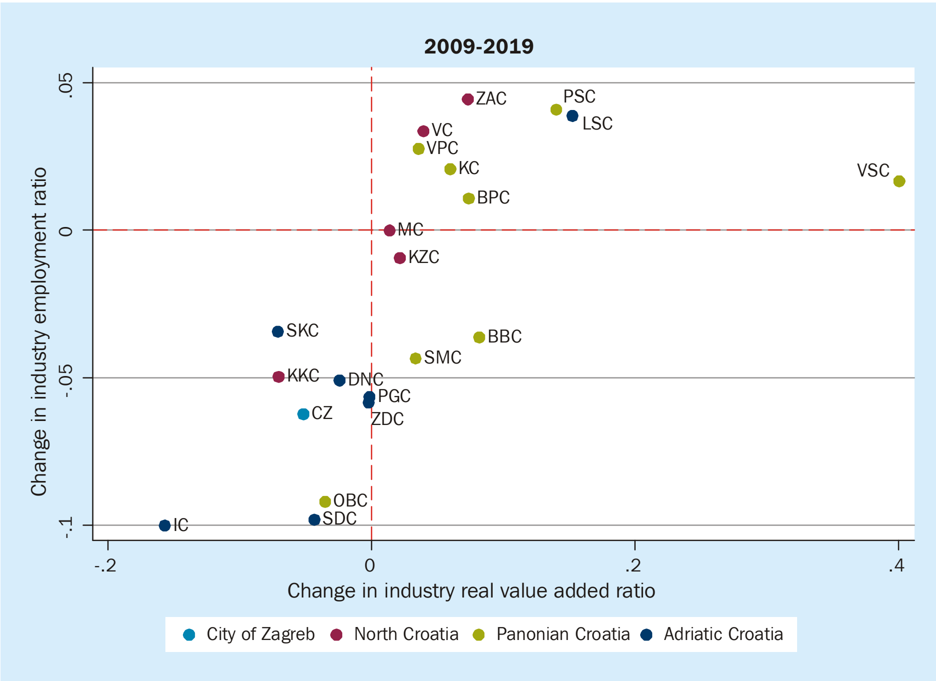
Sources: Authors' calculations based on Eurostat's comprehensive database Digital Economy and Society Statistics and the FINA database.

4.1.3 Deindustrialization/reindustrialization in Croatia

Figure 4 shows the rate of reindustrialization or deindustrialization in the period between 2009 and 2019 in all 21 Croatian counties (NUTS 3 regions). The vertical axis represents the share of employment in industry sector in relation to total employment in each county, while the horizontal axis represents the share of real value added in industry sector in relation to total real value added in each county. Changes presented in this figure are simple differences between shares in the last (2019) and the first (2009) year of observation.

All counties are placed in one of the four areas on the graph, depending on their combination of industry employment share and turnover share change. Counties which have experienced the most deindustrialization are placed in bottom-left part of the diagram, which means that both the employment share and turnover share of industry sector declined in 2019 compared to 2009. On the opposite end are counties which have experienced an increase in these two shares, and they are situated in the upper-right part of the diagram. Most of the counties which experienced an increase in the share of both values are in NUTS 2 regions named Pannonian Croatia and North Croatia, whereas most of the counties which experienced a decrease of both shares are in Adriatic Croatia (NUTS 2)[19]. Most counties[20] in which an increase of industrial production was observed in the analyzed period are located in Pannonian Croatia and North Croatia NUTS 2 regions.

Figure 4 **The rate of deindustrialization and reindustrialization in the 2009 – 2019 period in Croatian counties**



Notes: This figure shows the rate of deindustrialization in the 2009 – 2019 period in Croatian counties. The Y-axis represents the share of employment in the industry sector in relation to total employment in each county, while the X-axis represents the share of real value added in the industry sector in relation to total real value added in each county. Counties are the following: ZAC – Zagreb county, KZC – Krapina-Zagorje county, SMC – Sisak-Moslavina county, KC – Karlovac county, VC – Varaždin county, KKC – Koprivnica-Križevci county, BBC – Bjelovar-Bilogora county, PGC – Primorje-Gorski Kotar county, LSC – Lika-Senj county, VPC – Virovitica-Podravina county, PSC – Požega-Slavonia county, BPC – Brod-Posavina county, ZDC – Zadar county, OBC – Osijek-Baranja county, SKC – Šibenik-Knin county, VSC – Vukovar-Srijem county, SDC – Split-Dalmatia county, IC – Istria county, DNC – Dubrovnik-Neretva county, MC – Međimurje county, CZ – City of Zagreb.

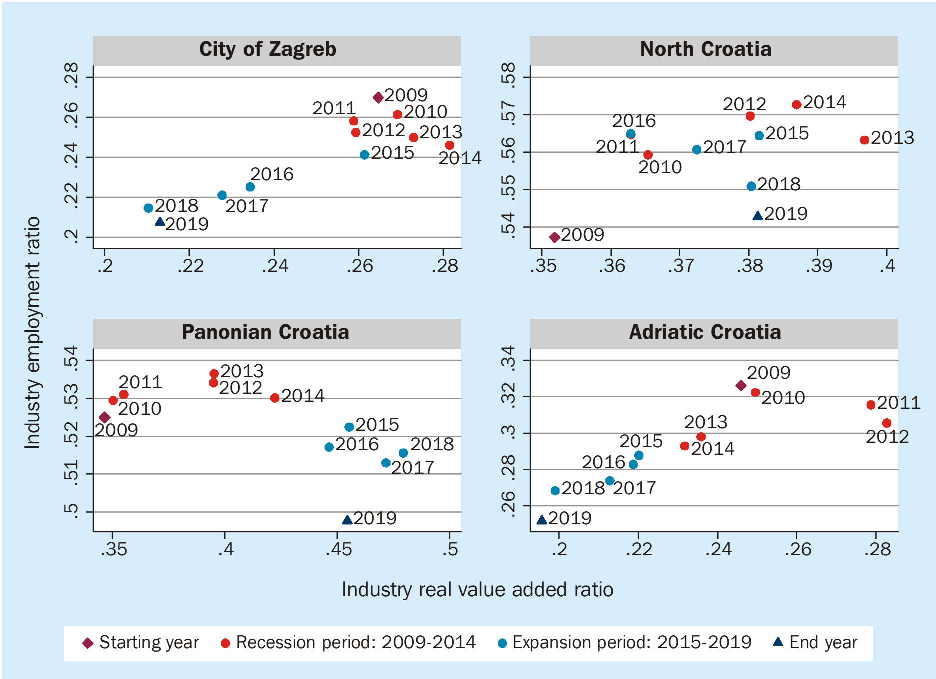
Source: Authors' calculations based on the FINA database.

[19] Lika-Senj county is the only exception. Within this county, there are smaller cities on the coast compared to other counties on the Adriatic coast. The central town of this county, Gospić, is also located in the mainland.

[20] The exceptions are Osijek-Baranja county and Koprivnica-Križevci county.

Figure 4 shows the rate of reindustrialization or deindustrialization for each year in the period between 2009 and 2019 in all four Croatian NUTS 2 regions. The vertical axis represents the share of employment in the industry sector in relation to total employment in each region, while the horizontal axis represents the share of real value added in the industry sector in relation to total real value added in each region. Each data-point corresponds to a combination of these two ratios for a given year. Additionally, we have also added another dimension, indicating a position of industry employment – industry value added combination with respect to the state of the overall Croatian economy[21].

Figure 5 **Industry employment and real value-added ratio in Croatian NUTS 2 regions over the analyzed period**



Notes: X-axis and Y-axis scales are different. This figure shows the rate of deindustrialization in the 2009 – 2019 period in Croatian NUTS 2 regions. The Y-axis represents the share of employment in industry sector in relation to total employment in each region, while the X-axis represents the share of real value added in the industry sector in relation to the total value added in each region. Regions are defined according to NUTS 2021 classification, available at https://ec.europa.eu/eurostat/web/nuts/background.

Source: Authors' calculations based on the FINA database.

This graph clearly illustrates differences in reindustrialization/deindustrialization pattern among the Croatian NUTS 2 regions. A decrease of industry employment and industry real value are observed in Adriatic Croatia and the City of Zagreb in the 2015-2019 period. A combination of these two effects indicates deindustrialization and increase of importance in

[21] The Croatian economy recorded a negative growth rate in the 2009-2014 period. It then picked up in 2015 and was on the recovery path, including the last year of observation, 2019.

terms of value added and employment in both regions in the period of economic growth. However, in Pannonian Croatia, a decrease of industry employment combined with an increase of industry real value added were observed. These changes can be explained by sectoral restructuring and quality upgrading of their manufacturing exports of this region.

4.2 Model estimates

An estimation of our model is presented in Table 2. Results are presented using three different estimators: (1) pooled OLS estimator in columns 1-3; (2) fixed effect estimator in columns 4-6[22]; and (3) random effect estimator in columns 7-9. In addition, each estimator was separately estimated for industry (this sector includes manufacturing and energy sectors) and services sectors.

Obtained results across all three estimators suggest a positive significant relationship between the adoption of ICT technologies and firm productivity, thus corroborating the domination of ICT technologies in production processes of Croatian firms, i.e., categories related to the core ICT index. On the other side, pooled OLS and fixed effect estimators are suggesting a negative relationship between adoption of digital technologies and firm, which can partly be explained by the fact that the use of categories which this index consists of is growing, i.e., these technologies passed the initial phase in terms of use by the companies, but are not yet accepted as a common standard for most firms in Croatia. Finally, a share of industry in a region where a firm operates (expressed as a percentage of labor employed in industry sector), is positively correlated to firm productivity, meaning that firms can benefit from the "industry environment". Both fixed intangible assets (e.g., R&D expenditure, patents, trademarks) and average wage bills are positively associated with firm productivity and their effects are significantly different from zero. This is not surprising given that these variables approximate the level of know-how in the firm and the level of human capital. Analyzing the effects of time-invariant firm characteristics (available only in pooled OLS and random effects model), one must keep in mind that our benchmark average firm operates in high-tech manufacturing sector, is located in the Zagreb region, is a micro firm, and is both an importer and an exporter.

Looking at the industry sector, all subsectors show a negative productivity premium with a reference to high-tech manufacturing, this may imply that spillovers generate labour-saving productivity improvements (Bishop, 2007: 288) On the other hand, a somewhat surprising finding is that, in the service sector, all subsectors show a positive productivity premium with reference to high-tech manufacturing, especially less knowledge-intensive market services (LKIS). Regarding LKIS, these results can be explained by higher TFP of this

[22] For panel data fixed effects model, we used fixed effects on every firm, thus losing all time-invariant firm characteristics, such as technology sector or region.

sector in comparison to other ones[23] and how companies within LKIS use technology. On average, companies within LKIS sector, alongside their counterparts in high-tech and medium high-tech sectors, are among the best TFP performers in Croatia. On the other hand, positive effects on companies within the LKIS can be explained by characteristics of companies within LKIS sector, where these companies use different technologies sourced from other companies in their activities (for example from the ICT sector), i.e., they do not use the technology produced by themselves. This means that an increase of TFP, parallel with technology production in high technology sector, implies an increase of TFP parallel with an increase of technology adoption in LKIS. With reference to the Zagreb region, there is a negative premium for all other Croatian regions in terms of TFP. The only exception is the pooled OLS estimator for the region of Adriatic Croatia, which can mostly be attributed to heavy dependence on tourism in this region. In terms of firm size, across all estimators and all sectors, it seems that all firms larger than micro firms are recording a positive productivity premium and the highest positive productivity premium being recorded in large-sized firms. Finally, trade status also plays an important role in explaining variations in firm productivity, showing that firms concentrating solely on domestic market fare the worst.

[23] According to technological intensity and based on NACE Rev. 2 at 2-digit level for compiling aggregates, high technology and medium-high technology, together with medium-low and low technology, belong to aggregation of the manufacturing sector used by Eurostat, following a similar approach as for manufacturing. In a similar way, Eurostat defines that sector knowledge intensive services or less knowledge-intensive services belong to aggregation of the service sector. For more details please see Eurostat (2010).

Table 2 **Estimations of our model (Equation 1)**

	Pooled OLS estimators			***Fixed effects estimators***			***Random effects estimators***		
	All sample	**Industry**	**Services**	**All sample**	**Industry**	**Services**	**All sample**	**Industry**	**Services**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
ICT	0.9876***	0.5296*	1.0426***	0.0347*	-0.2382	0.1815**	0.3741***	-0.2246	0.4537***
	(0.0738)	(0.2789)	(0.0761)	(0.0124)	(0.2474)	(0.0761)	(0.0684)	(0.2376)	(0.0698)
DIGTECH	-0.6441***	-0.6367*	-0.6764***	-0.3007***	-0.1276	-0.2197***	-0.0951	-0.2578	-0.0194
	(0.0827)	(0.3291)	(0.0850)	(0.0685)	(0.2561)	(0.0697)	(0.0688)	(0.2537)	(0.0694)
SHINDEMP	-0.1949***	0.0444	-0.2316***	0.1646***	0.3822***	0.1504***	0.1374***	0.2770**	0.1300***
	(0.0298)	(0.0854)	(0.0313)	(0.0347)	(0.1332)	(0.0347)	(0.0332)	(0.1171)	(0.0335)
Fixed intangible assets	-0.0008*	0.0023	-0.0015***	0.0031***	0.0038**	0.0029***	0.0036***	0.0057***	0.0032***
	(0.0005)	(0.0016)	(0.0005)	(0.0005)	(0.0018)	(0.0005)	(0.0005)	(0.0017)	(0.0005)
Age	0.0216***	0.0146***	0.0244***	0.0322***	0.0387***	0.0308***	0.0314***	0.0371***	0.0308***
	(0.0010)	(0.0027)	(0.0010)	(0.0012)	(0.0042)	(0.0012)	(0.0010)	(0.0032)	(0.0010)
Age squared	-0.0007***	-0.0003***	-0.0009***	-0.0010***	-0.0012***	-0.0010***	-0.0009***	-0.0010***	-0.0009***
	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0001)	(0.0000)
Average wage	0.8244***	0.9209***	0.8107***	0.6878***	0.7687***	0.6771***	0.7213***	0.8167***	0.7086***
	(0.0045)	(0.0165)	(0.0047)	(0.0034)	(0.0133)	(0.0034)	(0.0031)	(0.0116)	(0.0031)
Technological sector (benchmark: High-tech manuf.)									
Medium high-tech manuf.	-0.2046***	-0.2221***					-0.0736	-0.2401***	
	(0.0268)	(0.0446)					(0.0548)	(0.0790)	
Medium low-tech manuf.	-0.7902***	-0.8046***					-0.7343***	-0.8114***	
	(0.0271)	(0.0573)					(0.0567)	(0.0847)	
Low-tech manuf.	-0.1058***	-0.1126*					-0.0698	-0.1814**	
	(0.0232)	(0.0599)					(0.0485)	(0.0782)	
Energy	-1.1227***	-1.1299***					-1.0376***	-0.9520***	
	(0.0399)	(0.0665)					(0.0666)	(0.0978)	
KIS, market	-0.7942***		0.1493***				-0.8184***		0.1666***
	(0.0208)		(0.0145)				(0.0467)		(0.0230)
KIS, high-tech	-0.9430***						-0.9604***		
	(0.0207)						(0.0476)		
KIS, other	-0.2543***		0.6869***				-0.2452***		0.7636***
	(0.0252)		(0.0198)				(0.0616)		(0.0459)
LKIS, market	0.2303***		1.1640***				0.0758		1.0604***
	(0.0210)		(0.0154)				(0.0461)		(0.0223)
LKIS, other	-0.3928***		0.5451***				-0.5227***		0.4585***
	(0.0438)		(0.0415)				(0.1260)		(0.1147)

Period (benchmark: Recession period 2010-2014)									
Period 2015-2019	-0.0095**	-0.0124	-0.0074*				-0.0178***	-0.0162	-0.0208***
	(0.0043)	(0.0134)	(0.0045)				(0.0037)	(0.0122)	(0.0038)
Region (benchmark: the Zagreb region)									
Panonian Croatia	-0.0020	-0.1345***	0.0183*				-0.1194***	-0.1847***	-0.1069***
	(0.0096)	(0.0287)	(0.0100)				(0.0149)	(0.0467)	(0.0155)
Adriatic Croatia	0.0259***	-0.1532***	0.0571***				-0.1152***	-0.2267***	-0.0918***
	(0.0098)	(0.0290)	(0.0103)				(0.0162)	(0.0493)	(0.0170)
North Croatia	-0.0927***	-0.2149***	-0.0750***				-0.1454***	-0.2462***	-0.1313***
	(0.0049)	(0.0170)	(0.0051)				(0.0113)	(0.0372)	(0.0116)
Firm size (benchmark: Micro firms)									
Small	0.7753***	0.6664***	0.7970***				0.3798***	0.3833***	0.3808***
	(0.0060)	(0.0169)	(0.0063)				(0.0067)	(0.0207)	(0.0069)
Medium	1.3752***	1.1819***	1.4395***				0.7657***	0.7493***	0.7674***
	(0.0163)	(0.0356)	(0.0181)				(0.0172)	(0.0413)	(0.0193)
Large	2.2145***	2.0427***	2.2538***				1.1932***	1.2322***	1.1607***
	(0.0386)	(0.0834)	(0.0410)				(0.0400)	(0.0922)	(0.0452)
Trade status (benchmark: Importer and exporter)									
No trade	-0.4899***	-0.4167***	-0.5092***				-0.2883***	-0.3104***	-0.2833***
	(0.0064)	(0.0179)	(0.0067)				(0.0074)	(0.0225)	(0.0077)
Importer only	-0.1253***	-0.1823***	-0.1254***				-0.1323***	-0.2017***	-0.1211***
	(0.0078)	(0.0244)	(0.0081)				(0.0079)	(0.0252)	(0.0081)
Exporter only	-0.2661***	-0.1440***	-0.2936***				-0.0981***	-0.0769***	-0.1016***
	(0.0074)	(0.0213)	(0.0077)				(0.0076)	(0.0225)	(0.0079)
Constant	3.2486***	2.3610***	2.4507***	4.4355***	3.5507***	4.4869***	4.2873***	3.5071***	3.4035***
	(0.0563)	(0.2126)	(0.0558)	(0.0436)	(0.1571)	(0.0449)	(0.0632)	(0.1732)	(0.0494)
N	348,456	49,250	299,206	348,456	49,250	299,206	348,456	49,250	299,206
R^2	0.4672	0.3772	0.4862	0.4672	0.3772	0.4862			
Adjusted R^2	0.467	0.377	0.486						
Number of firms				57,047	8,481	49,415	57,047	8,481	49,415

*Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are in parentheses. Industry sector consists of manufacturing and energy. In industry-specific analysis and in the analysis using all samples, high-tech manufacturing was used as the benchmark sector. In service-specific analysis high-tech knowledge-intensive services were used as the benchmark.*

Sources: Authors' calculations based on Eurostat's comprehensive database, Digital Economy and Society Statistics, and the FINA database.

5 Conclusion

The goal of this paper was to estimate the adoption effects of different technologies and the rate of industry employment share on firm productivity. To this purpose, an analysis was carried out using a financial dataset of Croatian enterprises in the 2009–2019 period (FINA) and Eurostats' Digital Economy and Society data, based on "Community survey on ICT usage and ecommerce in enterprises" (DES). Using a list of selected variables from the latter dataset, based on their availability for Croatia, we have identified two key principal components that explain a significant share of variation in those variables. Based on the variable loadings on each component, we have identified two indices to capture the variation of adoption of ICT technologies and digital technologies related to Industry 4.0. A descriptive analysis revealed no significant differences in productivity levels between high and low digital technologies related to Industry 4.0 adoption firms. However, when we compared firms with high and low levels of ICT technology adoption, the former groups recorded a higher productivity level. Additionally, using the FINA dataset, we have calculated the rate of deindustrialization/reindustrialization in each of 21 Croatian counties (NUTS 3 regions), which we defined as the employment share in industry sectors (NACE 1-digit sectors C, D and E) in total employment in each county across the observed period.

These adoption rates of different technologies and the shares of industry employment in total employment, approximating, over time, the rate of deindustrialization or reindustrialization, were then linked to firm performance, which was proxied using total factor productivity. In addition to these variables, the set of covariates used in regression also included controls for firm age, the level of their workforce skills, firms' know-how, their size, their trade orientation and dummies for different sector, region, and time effects. Results of our empirical specification indicate a positive significant relationship between adoption of ICT technologies and firm productivity, and a negative relationship between adoption of digital technologies and firm productivity. Furthermore, this seems to be a positive premium on productivity for larger-sized firms, firms participating in international trade, and firms situated near to key international markets (i.e., located in the Zagreb region).

This research is not without limitations and open questions for future research. The standard challenge in using regression methodologies on production function approach is the possibility of an unobserved covariate affecting the outcome. Given our available data, we controlled for firm-level characteristics such as age, sector, county, trade orientation, size. Using a rather rich firm-level dataset we were also able to proxy for human capital (e.g., average wage) and firm indebtedness (e.g., debt ratio). Nonetheless, one possible area for future research is to better capture the effects of other variables related to digital technologies associated with Industry 4.0, such as the use of big data, cloud computing or robotization in production process (we hope that datasets about these variables will be suitable for it). Finally, we analyze the effects of digital adoption and deindustrialization on firm productivity, while these two processes may have also generated positive spillovers to other firms, such as consultants or suppliers of equipment, which we do not estimate. An additional interesting area for future research would also be to increase the time span of the analysis to capture long-term trends in technology absorption capacity and to estimate the effects of macroeconomic shocks, such as the financial crisis towards the latter part of the 2000s.

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Appendix

Table 3 **Correlation matrix of digital adoption variables**

	e_cuse	e_iacc	e_webacc	e_awsval	e_axsval	e_eturn	e_ecom	e_web	e_webot	e_webper	e_esell
e_cuse	1.00										
e_iacc	0.94	1.00									
e_webacc	0.28	0.32	1.00								
e_awsval	0.04	0.05	0.14	1.00							
e_axsval	-0.18	-0.23	0.03	0.21	1.00						
e_eturn	-0.14	-0.17	0.10	0.56	0.75	1.00					
e_ecom	0.41	0.42	0.29	0.36	0.05	0.22	1.00				
e_web	0.39	0.50	0.68	0.11	-0.24	-0.15	0.51	1.00			
e_webot	0.19	0.22	0.48	0.43	0.00	0.22	0.46	0.43	1.00		
e_webper	0.14	0.19	0.36	0.42	-0.05	0.15	0.46	0.48	0.63	1.00	
e_esell	0.06	0.07	0.40	0.46	0.20	0.46	0.53	0.25	0.59	0.37	1.00
e_iuse_gt50	0.37	0.41	0.16	0.15	-0.10	-0.07	0.63	0.56	0.35	0.44	0.23
e_webord	0.10	0.15	0.56	0.46	0.04	0.28	0.50	0.46	0.76	0.54	0.73
e_webvac	0.22	0.29	0.25	0.17	0.00	0.06	0.52	0.53	0.33	0.38	0.10
e_crmstr	0.30	0.35	0.51	0.20	0.09	0.14	0.55	0.66	0.43	0.50	0.26
e_webctm	0.14	0.18	0.46	0.45	0.03	0.27	0.55	0.45	0.66	0.54	0.59
e_itsp2_or_rcr2	0.33	0.36	0.33	0.13	0.00	0.02	0.64	0.59	0.31	0.43	0.17
e_erp1	0.15	0.21	0.47	-0.01	0.10	0.10	0.37	0.56	0.21	0.27	0.14
e_ispdf_ge30	0.17	0.25	0.31	-0.05	-0.04	-0.08	0.34	0.49	0.24	0.17	0.07
e_sisc	0.21	0.14	0.17	0.24	0.16	0.21	0.35	0.03	0.21	0.26	0.32
e_cc	0.29	0.35	0.14	0.17	-0.06	0.00	0.58	0.52	0.30	0.43	0.24
e_siscall	0.15	0.08	0.07	0.49	0.23	0.38	0.37	-0.01	0.22	0.28	0.30

	e_iuse_gt50	e_webord	e_webvac	e_crmstr	e_webctm	e_itsp2_or_rcr2	e_erp1	e_ispdf_ge30	e_sisc	e_cc	e_siscall
e_cuse											
e_iacc											
e_webacc											
e_awsval											
e_axsval											
e_eturn											
e_ecom											
e_web											
e_webot											
e_webper											
e_esell											
e_iuse_gt50	1.00										
e_webord	0.31	1.00									
e_webvac	0.53	0.18	1.00								
e_crmstr	0.62	0.37	0.73	1.00							
e_webctm	0.25	0.75	0.29	0.38	1.00						
e_itsp2_or_rcr2	0.66	0.19	0.73	0.73	0.22	1.00					
e_erp1	0.30	0.21	0.60	0.67	0.23	0.57	1.00				
e_ispdf_ge30	0.38	0.28	0.46	0.48	0.20	0.48	0.48	1.00			
e_sisc	0.18	0.15	-0.02	0.12	0.24	0.23	-0.08	-0.43	1.00		
e_cc	0.70	0.31	0.53	0.51	0.29	0.61	0.33	0.52	-0.08	1.00	
e_siscall	0.15	0.08	0.07	0.49	0.23	0.38	0.37	-0.01	0.22	0.28	0.30

Table 4 **Principal component analysis results**

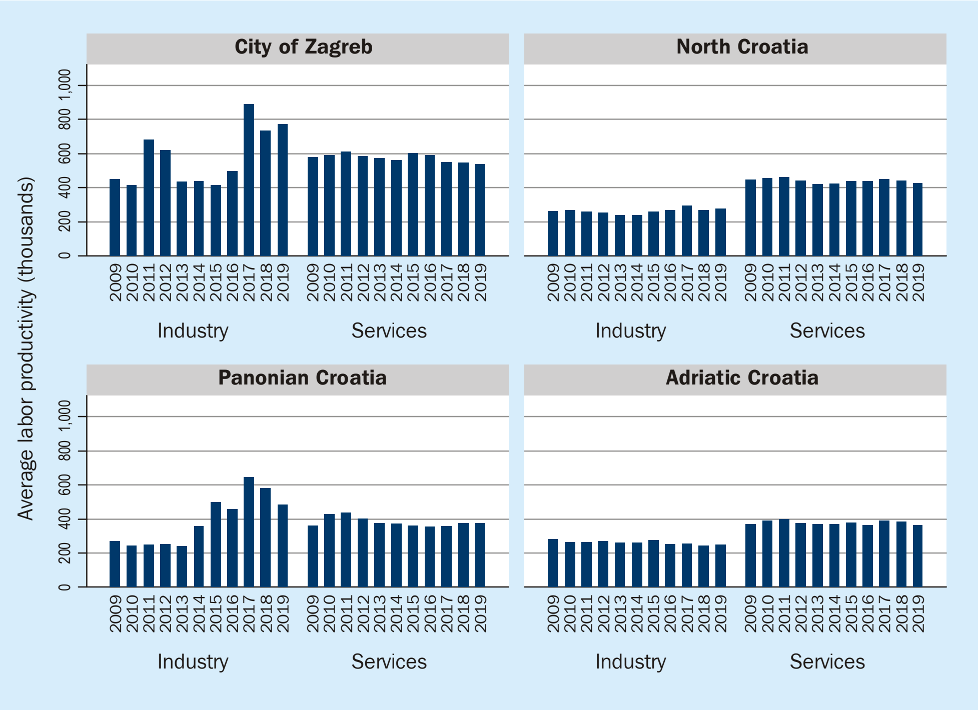
Panel A: Eigenvalue

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	7.80032	4.30951	0.3546	0.3546
Comp2	3.49081	1.42465	0.1587	0.5132
Comp3	2.06616	0.240089	0.0939	0.6071
Comp4	1.82607	0.55237	0.083	0.6902
Comp5	1.2737	0.179119	0.0579	0.748
Comp6	1.09458	0.372388	0.0498	0.7978
Comp7	0.722194	0.191643	0.0328	0.8306
Comp8	0.530552	0.0461143	0.0241	0.8547
Comp9	0.484438	0.061858	0.022	0.8768
Comp10	0.42258	0.043612	0.0192	0.896
Comp11	0.378967	0.0476117	0.0172	0.9132
Comp12	0.331356	0.0451954	0.0151	0.9283
Comp13	0.28616	0.0721161	0.013	0.9413
Comp14	0.214044	0.0108739	0.0097	0.951
Comp15	0.20317	0.0210177	0.0092	0.9602
Comp16	0.182153	0.033079	0.0083	0.9685
Comp17	0.149074	0.0065676	0.0068	0.9753
Comp18	0.142506	0.0104437	0.0065	0.9818
Comp19	0.132062	0.0131007	0.006	0.9878
Comp20	0.118962	0.0176816	0.0054	0.9932
Comp21	0.10128	0.0524176	0.0046	0.9978
Comp22	0.0488626	.	0.0022	1

Panel B: Eigenvector

Variable	1st principal component	2nd principal component
e_cuse	0.1602	-0.1499
e_iacc	0.1805	-0.1853
e_webacc	0.2172	0.0139
e_awsval	0.1497	0.3214
e_axsval	0.0079	0.2641
e_eturn	0.0739	0.375
e_ecom	0.2887	0.0468
e_web	0.2776	-0.1838
e_webot	0.2488	0.1659
e_webper	0.2459	0.0997
e_esell	0.199	0.2985
e_iuse_gt50	0.2535	-0.1256
e_webord	0.2429	0.2052
e_webvac	0.2426	-0.1711
e_crmstr	0.2892	-0.1092
e_webctm	0.2377	0.1972
e_itsp2_or~2	0.2681	-0.1541
e_erp1	0.2055	-0.1728
e_ispdf_ge30	0.1787	-0.2653
e_sisc	0.093	0.2792
e_cc	0.2378	-0.1596
e_siscall	0.1043	0.3185

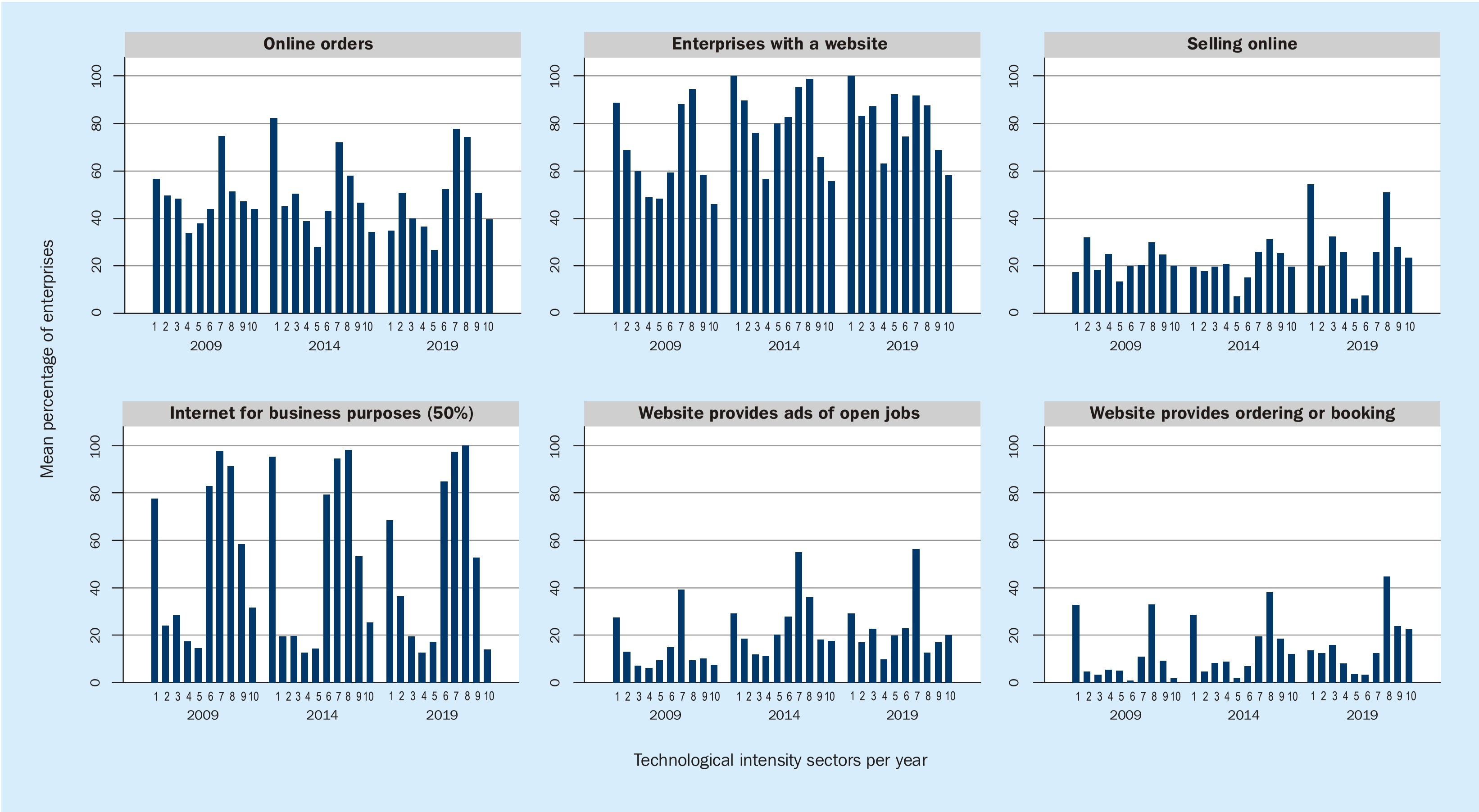
Figure 6 **Labor productivity distribution across different Croatian NUTS 2 regions and sectors over time**



Notes: Regions are defined according to NUTS 2021 classification, available at https://ec.europa.eu/eurostat/web/nuts/background. Industry is defined as NACE 1-digit sectors C, D and E. Services are defined as NACE 1-digit sectors G, H, I, J, L, M and N.

Source: Authors' calculations based on the FINA database.

Figure 7 **Diffusion of ICT technologies across sectors and time**



Notes: This figure shows the average adoption rate of selected digital technologies in three selected years in the following technological sectors: 1 – High-tech manufacturing; 2 – Medium high-tech manufacturing; 3 – Medium low-tech manufacturing; 4 – Low-tech manufacturing; 5 – Energy; 6 – Market knowledge-intensive services; 7 – High-tech knowledge-intensive services; 8 – Other knowledge-intensive services; 9 – Market less knowledge-intensive services; 10 – Other less knowledge-intensive services. Definitions of these sectors are available at https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

Source: Authors' calculations based on Eurostat's comprehensive database Digital Economy and Society Statistics.

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