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Article

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The Digital Transformation of European Union Countries before and during COVID-19

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Abstract

Background: The transformation of business and the economy is a key business problem, and its importance was further heightened during the COVID-19 pandemic, with the increased pressure on enterprises. Hence, the digital readiness of their business will likely determine its future competitiveness in the field. Objectives: The paper addresses the issue of digital readiness for business, with the aim of examining similarities and differences in the digital readiness of European Union countries. The main focus is on identifying the changes during the first two years of the pandemic. Methods/Approach: We conducted a factor analysis and hierarchical cluster analysis based on selected indicators. The results revealed some significant differences. Results: While the countries that lead in digital readiness remained the same, there were relatively large differences in the classification of other EU countries. Some countries, such as Latvia or Slovenia, significantly improved in many aspects of digital readiness during the pandemic. On the other hand, Bulgaria and Romania are still included in the same cluster, representing an overall low digital readiness. Conclusion: Enterprises in more developed countries also have a higher level of digital readiness. Although COVID-19 had a positive impact on digital readiness in some less developed countries, the impact is only partial, indicating a need for stronger actions to bridge the digital divide at the EU level. These findings provide a hopeful outlook, suggesting that with the right actions, the digital divide in the EU can be effectively bridged.

Keywords: digital transformation; business digital readiness; digital economy; COVID-19 pandemic.

JEL classification: O33, L21, H12
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Introduction

Digitisation and digitalisation in businesses have been one of the key trends in recent years, with organisations around the world trying to adapt to the new demands of the digital era. Digital transformation includes both digitisation and digitalisation (Verhoef et al., 2021). It represents the use of digital technology that radically improves the performance or reach of enterprises (Westerman et al., 2011). Hence, it is one of the key issues that companies' management should address. The importance of this digital transformation has even further increased during the COVID-19 pandemic, which can be seen as a business emergency that has created the need for organisations to be resilient and versatile (Khalil et al., 2022). Due to the adoption of digital technologies, SMEs can increase their agility and change their business models in weeks, if not days (Tsou & Chen, 2023). The utilisation of digital technologies can increase productivity and profitability, and digitally advanced firms have better chances of surviving any recession (Döhring et al., 2021). However, tolls related to digital transformation, such as big data, e-orders, supplier-customer man-agreement, and e-commerce, were significantly underdeveloped in SMEs in the recent past (OECD, 2021). In our case, the term digital readiness is used as an indicator of the potential success of digital transformation.

The pandemic has affected businesses around the world, forcing them to quickly adapt and implement digital transformation to continue their business and be successful (Qureshi et al., 2020). During the first two years of the pandemic, there was a significant surge in the utilisation of online meetings and organisations across the EU. Employees had to acclimate to a variety of digital platforms for communication and virtual meetings (Khawaja et al., 2023).

Changing customer behaviour, new regulations, and social distancing rules meant unprecedented changes in business for all types of firms in every country. However, differences in levels of digitalisation, as well as different business environments in EU countries, could have a significant impact on the intensity of such a transformation (Khawaja et al., 2023). By comparing the situation before and during the pandemic, our research identifies and explores significant differences in the digital readiness of businesses and its trends in EU countries. Our main aim is to examine differences in the digital transformation of business among EU countries and assess the changes during the COVID-19 pandemic. To fulfil this aim, factor analysis and hierarchical cluster analysis are used on a range of indicators, capturing the dynamic changes in digital readiness during the pandemic. Based on the empirical evidence, clusters of EU countries have been identified, and their characteristics have been compared before and during the pandemic. With an in-depth analysis of selected indicators and their trends, the paper contributes to a deeper understanding of the impact of the pandemic on the digital transformation of business.

In the next section, an overview of the literature related to digital transformation is presented. The focus is on the potential impact of the pandemic. Further sections are devoted to the description of the methodology and data, followed by an explanation of key results and discussion. The final section summarises the findings and conclusions.

Literature review

This section systematises and compares the results of the studies devoted to digital transformation in EU countries. It first focuses on the issue of digital business transformation and potential options for its assessment. Then, the literature review moves on to the effect of the COVID-19 pandemic on businesses' digital readiness.

Digital transformation in the EU countries

Several recent studies have examined the issue of the digital transformation of business in the EU, including those by Wang (2023). Kääriäinen et al. (2021), Borowiecki et al. (2021), Kinnunen et al. (2019), and Bouwman et al. (2019). Most of them analysed digitalisation and digital capital accumulation or examined problems related to digitalisation processes in companies. Our paper builds on the previous research but pays significantly more attention to various indicators of digital readiness in firms. It also classifies EU countries according to digital readiness before and after the pandemic. In some ways, Kozhevina et al. (2017) had previously employed a similar approach. They created the total digital economy index using various metrics that are appropriate, especially for the Russian economy. Our research applies different indicators and factors with a focus on EU countries. The European Commission is annually monitoring digital improvements in EU countries via Digital Economy and Society Index (DESI) reports. The key areas of concern are human capital, connectivity, integration of digital technology, digital public services, and research and development in ICT. Based on the overall results, Denmark, Finland and Sweden are ranked as the three top-performing countries. On the other hand, countries such as Romania, Bulgaria and Greece are usually placed at the end of the ranking. Tomičić Furjan et al. (2020) argue that digital transformation is a very complex problem with many challenges. Our analysis is focused on some specific aspects of digital readiness and digital transformation. With this narrower approach, it is possible to analyse and assess the digital readiness of companies in the EU. A similar strategy has been used, for example, by Hunady et al. (2022), to evaluate the digital readiness in EU countries.

The global trend of digitalisation puts significant pressure on business in the EU. Companies in the EU need to catch up to main global players like China and the US in sales related to information and communication technologies (Schweer et al., 2017). Furthermore, the current state of digital readiness needs to be more distributed among EU countries (Kinnunen et al., 2019). Firms with businesses located in newer member states especially are struggling significantly with digital transformation processes. These processes require some fundamental changes in business models Bouwman et al. (2019). Companies should redevelop their current strategies and introduce new processes built mostly on emerging digital technologies (Kääriäinen, 2021). This transformation can be affected by many external circumstances, while the pandemic can be considered as one of the most prominent issues. Hence, this problem needs to be examined in more detail.

Over the previous two decades, digitalisation has received some significant attention in economic and business research. However, most of it was consecrated to e-commerce (Zaied, 2012). Due to its convenience for both buyers and sellers, e-commerce fulfils its potential to accelerate the expansion of businesses around the world (Kasemsap, 2018). Despite the indisputable importance of e-commerce, the current digital economy includes a much wider scope of problems. Many emerging digital technologies are becoming essential for increasing business productivity. This includes, for example, the usage of data mining (Topalović & Azzini, 2020) and cloud computing services (Dincă et al., 2019). Moreover, social networks have also become important channels for communication, marketing, and selling. The application of social networks for B2B and B2C communication and e-commerce has been examined, for example, by Ballestar et al. (2019) and Davidaviciene et al. (2017). Big data, cloud, mobile, and social network technologies, especially, have become crucial parts of business infrastructure while improving the financial valuation of the firm (Schwertner, 2017). Big Data contains large datasets retrieved from diverse data

sources and types. The comprehensive usage of such data is enabled only by emerging technology and innovative data management tools. Enterprises using such tools can significantly benefit in several ways, such as process innovation, matching customer skills as well as improved risk and quality management (Urbinati, 2019). Big data analysis is also partly related to cloud computing. This digital solution allows timely, on-demand access to a common pool of important business data and information. Its adoption in the firm can improve internal processes and reduce the overall cost (Schwertner, 2017). The application of the mentioned technologies in firms was used as one of the dimensions of the evaluation of digital readiness. A digital readiness index capturing the usage of selected digital technologies has been previously used to compare the digital readiness of smart ports (Philipp, 2020). Furthermore, Zalite and Zvirbule (2020) also used a similar methodology to examine the digital readiness of higher education institutions in EU countries. The digital readiness of SMEs has also been previously examined in Italy (Pirola, 2019).

The potential effect of a pandemic on digital transformation

The COVID-19 pandemic has precipitated profound transformations in the global economy, acting as a disruptive catalyst for the accelerated adoption of emerging technologies, notably digitalisation. Despite variations in workplace dynamics across professions, industries, and geographical locations, the challenges stemming from the pandemic have demonstrated a remarkable commonality (Šola et al., 2021).

The pandemic may permanently increase the demand for already-existing digital services and pave the way for the development of brand-new ones (Döhring et al., 2021). However, the digital transformation represented a big challenge for the business sector as well as for the government. All organisations, regardless of their size or activities, are significantly affected by the consequences arising from both digital transformation and the COVID-19 pandemic (Burlea-Schiopoiu, 2023). New measures and social distancing policies created a favourable environment for a fundamental transformation to a new digital society (Ganichev & Koshovets, 2021). During the pandemic, digital infrastructure witnessed a "positive demand shock" represented by the shift towards online business and digital society (Banga & Te Velde, 2020).

One of the main pandemic-related phenomena is working from home (Adžić & Al-Mansour, 2021). This previously less common type of work has become dominant in some jobs. Most firms introduced new work-from-home policies and enabled the remote work of their employees through extensive purchases of extra computers, tablets, and cell phones (Kraus et al., 2020). At the same time, this represents one small but important step closer to the digital transformation of companies that did not have such possibilities until then.

Khalil et al. (2022), based on 96 surveyed SMEs, showed that digital technology usage has helped SMEs survive the pandemic. The authors found that digital technologies help businesses in developing countries become more resilient in general. They argue that supporting digital technologies is the main policy solution to the economic problems induced by the pandemic. Insufficient levels of digital readiness led to notably lower productivity among employees during the pandemic (Mustajab et al., 2020).

Additional investment in remote work capabilities and digital technologies enabled firms to maintain at least or even improve productivity. Advanced digital technologies such as those played a key role in recovery from economic problems caused by the pandemic and enabled remote education, employment, and services by reducing exposure to the virus (Al-Sartawi et al., 2021). Burlea-Schiopoiu (2023) found that the crisis caused by the COVID-19 pandemic led to many improvements in digital

capabilities and the development of new digital products. Overall, it notably advanced the digital transformation process. They also argue that pandemics positively influence organisations' implementation of digital transformation strategies.

Our research provides some new empirical evidence on the digital transformation of business in the EU during the pandemic. Moreover, it also shows unique findings on dynamics in the usage of digital technologies and changes in the classification of EU countries into groups based on their level of business digital readiness.

Methodology

Research questions and hypothesis

The paper examines the following research questions (RQ):

- RQ1: What indicators of business digital readiness have been changed the most during the pandemic?
- RQ2: How did the distribution of countries in individual clusters of digital readiness change during the pandemic?
- RQ3: How did the characteristics of each cluster change with respect to digital readiness during the COVID-19 pandemic?
- RQ4: To what extent has the pandemic affected the share of companies implementing measures to enable work from home through digital communication technologies?

Research questions are further followed by research questions, which enable a more detailed examination of these problems. The research hypotheses (H) are stated as follows:

- H1: The digital readiness of companies increased during the EU pandemic.
- H2: The countries that achieved the best digital readiness before the pandemic are still included in the best-performing cluster during the pandemic.
- H3: The characteristics of clusters after the pandemic changed significantly compared to before the COVID-19 outbreak.
- H4: During the pandemic, the share of companies that implemented measures to enable remote work from home through digital communication technologies increased.

Data

The analysis of the examined problem is based on secondary data retrieved from the Eurostat database (Digital Society: E-Business). Data are collected using the annual questionnaire survey, "EU survey on ICT usage and e-commerce in enterprises." Some questions in the questionnaire change every year. Only those indicators that are available for the years 2019 and 2021 have been used in our analysis. Selected indicators refer to digital readiness and the process of digital transformation in firms. The availability of data for both years was also an important criterion when selecting a set of indicators. Indicators are represented by 11 variables, which are described in Table 1.

Table 1
Description of variables used in the cluster analysis (years 2019 and 2021)

Variable	Description (2019 and 2021)
Providing portable devices to employees	Enterprises providing portable devices for mobile connection to the internet for their employees (% of enterprises with 10 or more employees in the economy without financial sector)
Online ordering on the website	Enterprises where the website provides online ordering or reservation or booking, e.g. shopping cart (% of enterprises with 10 or more employees in the economy without fin. sector)
ICT/IT training	Enterprises which are provided training to ICT/IT specialists to develop their ICT skills (% of enterprises with 10 or more employees in the economy without financial sector)
Using ERP software	Enterprises who have ERP software packages to share information between different functional areas (% of enterprises with 10 or more employees in the economy without financial sector)
Using software solutions for CRM	Enterprises using software solutions for Customer Relationship Management (CRM)
Using multimedia content-sharing websites	Enterprises using multimedia content-sharing websites, e.g. YouTube, Flickr, Picasa, SlideShare, etc. (% of enterprises with 10 or more employees in the economy without financial sector)
Using social networks	Enterprises using any social network (% of enterprises with 10 or more employees in the economy without financial sector)
Buying cloud computing services	Enterprises buying cloud computing services used over the internet (% of enterprises with 10 or more employees in the economy without financial sector)
Big data analytics	Enterprises using big data from smart devices or sensors Enterprises analysing big data from smart devices and sensors (% of enterprises with 10 or more employees in the economy without financial sector)
Using industrial robots	Enterprises using industrial robots (% of enterprises with 10 or more employees in the economy without financial sector)
Using service robots	Enterprises using service robots (% of enterprises with 10 or more employees in the economy without financial sector)

Source: Authors based on Eurostat database (EU survey on ICT usage and E-commerce in enterprises).

The set of selected indicators has been classified into three types of measures: essential steps (providing portable devices to employees, online ordering or reservations, and providing ICT training to specialists), slightly advanced digital tools (using ERP software, CRM software, multimedia sharing platforms, and social networks), and advanced tools (cloud computing services, big data analysis, and using industrial or service robots). Basic descriptive statistics for all variables are shown in Table 2.

As can be seen, the mean values for most of the variables are higher in 2021 compared to 2019. Most of the firms included in the survey reported that they are providing portable devices to employees, and more than half of them are also active on social networks. On the contrary, the use of big data analysis and robotics is still rather rare. Interestingly, there was a decrease in the usage of big data analytics from smart devices during the pandemic.

Table 2
Basic descriptive statistics of variables used in the analysis

	Mean (year 2019)	Std. Dev. (year 2019)	Mean (year 2021)	Std. Dev. (year 2021)	Min. (year 2021)	Max. (year 2021)
Providing portable devices (%)	**86.1%**	8.21	**87.78%**	6.31	74.00%	99.00%
Online ordering (%)	**20.7%**	7.52	**22.19%**	7.01	13.00%	37.00%
ICT/IT training (%)	**10.81%**	3.7	**10.63%**	3.56	4.00%	18.00%
Using ERP software (%)	**35.74%**	9.55	**36.81%**	10.42	17.00%	57.00%
Using software for CRM (%)	**29.89%**	10.56	**31.41%**	11.63	15.00%	54.00%
Multimedia content sharing(%)	**22.2%**	9.21	**28.04%**	10.45	11.00%	50.00%
Using social networks (%)	**55.33%**	14.22	**61.15%**	13.19	36.00%	84.00%
Cloud computing services(%)	**28.52%**	14.88	**42.81%**	17.16	13.00%	75.00%
Big data analytics (%)	**4.41%**	2.23	**3.89%**	2.42	1.00%	10.00%
Using industrial robots (%)	**4.5%**	2.2	**5.07%**	2.09	1.00%	9.00%
Using service robots (%)	**1.93%**	0.99	**2.15%**	0.99	1.00%	5.00%

Source: Authors based on data from the Eurostat database.

Statistical analysis

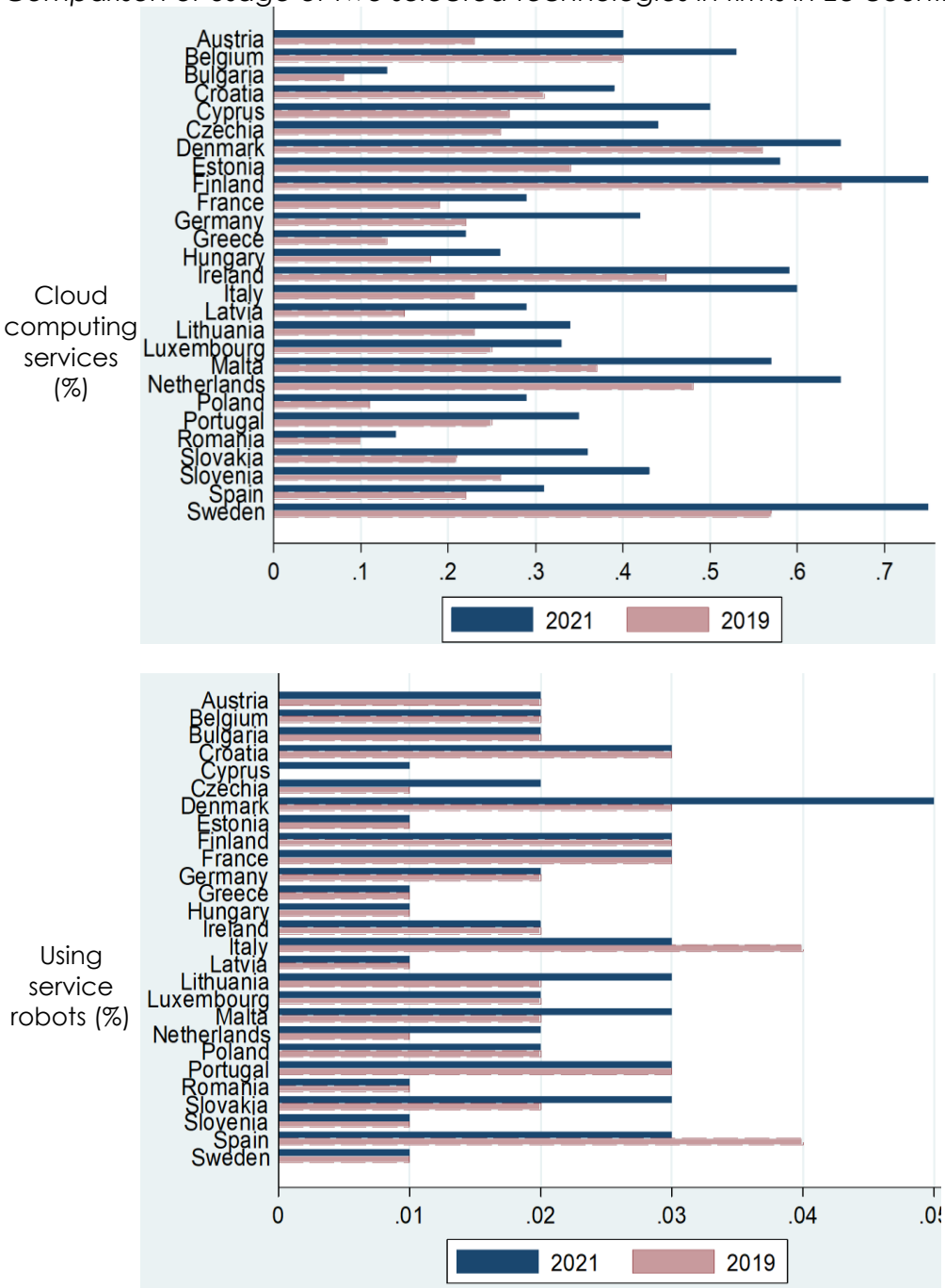
The variables mentioned capture the share of enterprises using the mentioned tools and are used as inputs into multidimensional statistical analysis. The analysis includes cluster analysis (CA) and principal component analysis (PCA). CA was used to classify countries into clusters with similar overall business digital readiness. Agglomerative hierarchical clustering was used in combination with the Ward linkage method and Euclidean distance calculation. Hierarchical cluster analysis is the method that seeks to construct a hierarchically arranged sequence of partitions for some given object set. The hierarchical clustering task is defined as finding a least-squares approximation to the proximity measure by an ultra-metric structure (Köhn, Hubert, 2009). Ward's method calculates the incremental sum of squares between objects. The pair of clusters is chosen to (locally) minimise the k-means cost of the clustering in the next step (Großwendt et al., 2019). Calinski and Harabasz indexes have been used to choose the optimal number of clusters. The differences in the classification of EU countries in individual clusters in both years have been examined. Moreover, PCA was applied to reduce the dimensions of the examined digital readiness to two principal components. This allows us to show and explain the characteristics of individual clusters while preserving most of their variability. PCA is a multivariate technique that extracts important information from the statistical data to represent it as a set of new orthogonal variables called principal components (Mishra et al., 2017). Clusters' characteristics have been compared mostly by displaying boxplots of both principal components. The main results of our analysis are shown and discussed in the next section of the paper.

Results

The analysis is focused on investigating the differences in the usage of selected digital tools in EU countries and comparing the situation before and during the pandemic. Firstly, the share of firms using selected advanced technologies has been examined. It can be assumed that their usage is directly affected by the pandemic, i.e., cloud computing services and service robots. Cloud computing services could be used more intensively during the pandemic due to remote work and the necessity of accessing data online. Even though service robots are still relatively new technology, they can be used more frequently due to pandemic social distancing regulations and

potential customers' reluctance to use human-operated services. The results are shown in Figure 1.

Figure 1
Comparison of usage of two selected technologies in firms in EU countries



Source: Authors based on data from the Eurostat database.

There are rather significant differences between EU countries in their usage of cloud computing and service robots. On one hand, there was a significant increase in the usage of cloud computing in all EU countries during the pandemic. On the other hand, there has been no such significant increase in the number of service robots.

Next, the differences in using the other five digital technologies between 2019 and 2021 have been compared. The differences are shown in percentage points in Table

3. The first two tools represent rather basic elements of digital readiness. As expected, the share of portable devices available to employees and online ordering has grown in most countries. The most significant increase in usage of portable devices has been recorded in Latvia, Bulgaria, and Romania. This is mostly due to the rather low levels of these countries before the pandemic. The share of firms with available online ordering grew the most in Romania and Greece. In the case of ERP and CRM software solutions, the results are rather mixed. There was an increase in usage in some countries, but there was also a drop in many countries. This is probably because the use of ERP and CRM solutions is less closely related to pandemic measures. Surprisingly, there has been no significant increase in big data analytics based on data from smart devices in most countries. There has even been a significant drop in usage in Lithuania and Slovenia. Perhaps the business was focused on other issues, and this type of data was less crucial for their business during the pandemic.

Table 3
Changes in the selected indicators between 2019 and 2021 in EU countries

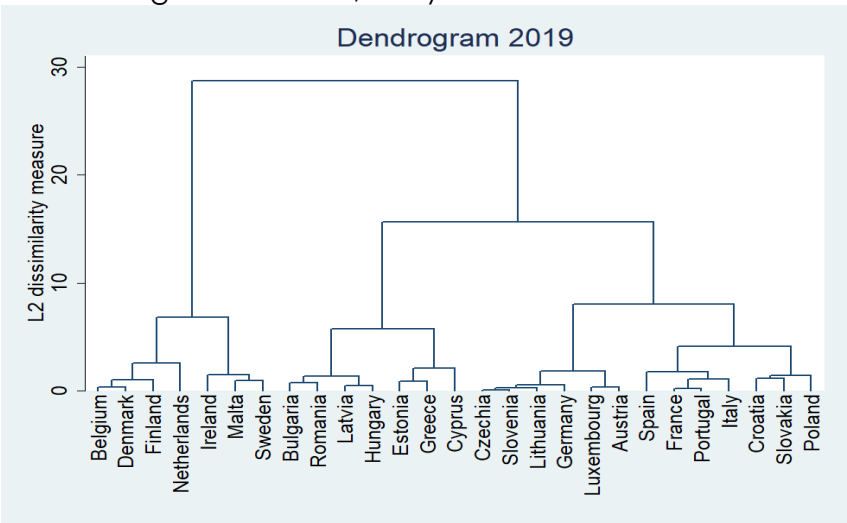
	Providing portable devices to employees (% of firms)	Online ordering on the website (% of firms)	Using ERP software in the company (% of firms)	Using software solutions for CRM (% of firms)	Big data analytics (% of firms)
Belgium			4p.p.	8p.p.	0p.p.
Bulgaria	10p.p.	0p.p.	-1p.p.	0p.p.	0p.p.
Czechia	2p.p.	2p.p.	0p.p.	-3p.p.	-2p.p.
Denmark			0p.p.	7p.p.	2p.p.
Germany	2p.p.		9p.p.	1p.p.	0p.p.
Estonia			-3p.p.	1p.p.	1p.p.
Ireland	0p.p.	-1p.p.	-4p.p.	0p.p.	-2p.p.
Greece	0p.p.	6p.p.	-3p.p.	0p.p.	
Spain	3p.p.	1p.p.	6p.p.	7p.p.	-2p.p.
France	1p.p.	1p.p.	-3p.p.	4p.p.	0p.p.
Croatia	2p.p.	2p.p.	-2p.p.	1p.p.	1p.p.
Italy	2p.p.	4p.p.	-3p.p.	-1p.p.	-1p.p.
Cyprus	3p.p.	3p.p.	1p.p.	6p.p.	0p.p.
Latvia	11p.p.	5p.p.	7p.p.	2p.p.	0p.p.
Lithuania		-3p.p.	-3p.p.	-4p.p.	-3p.p.
Luxembourg	2p.p.	1p.p.	-1p.p.	-2p.p.	-2p.p.
Hungary	4p.p.	0p.p.	7p.p.	3p.p.	1p.p.
Malta	0p.p.	3p.p.	7p.p.	7p.p.	2p.p.
Netherlands	0p.p.	3p.p.	-4p.p.	-4p.p.	-2p.p.
Austria		1p.p.	2p.p.	5p.p.	1p.p.
Poland	1p.p.	0p.p.	3p.p.	1p.p.	0p.p.
Portugal	0p.p.	4p.p.	10p.p.	-3p.p.	-2p.p.
Romania	8p.p.	6p.p.	-6p.p.	-3p.p.	-2p.p.
Slovenia	4p.p.	4p.p.	3p.p.	2p.p.	-4p.p.
Slovakia	3p.p.	1p.p.	0p.p.	0p.p.	-1p.p.
Finland	0p.p.		5p.p.	4p.p.	1p.p.
Sweden		4p.p.	-2p.p.	2p.p.	0p.p.

Note: p.p. – percentage points
Source: Authors based on data from the Eurostat database.

Cluster analysis was used to group all EU countries into clusters. It is based on the mentioned set of 11 indicators. More specifically, hierarchical clustering with Ward's linkage method was applied. Dendrograms graphically represent the key results. Two

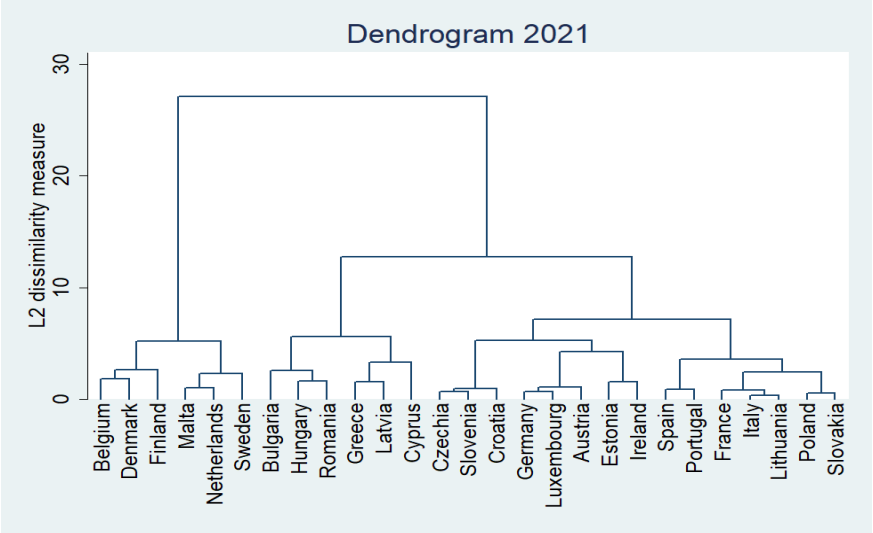
separate cluster analyses were applied to the data from 2019 (Figure 2) and 2021 (Figure 3).

Figure 2
Dendrogram showing the results of the cluster analysis of EU countries based on business digital readiness, the year 2019



Source: Authors based on data from the Eurostat database.

Figure 3
Dendrogram showing the results of the cluster analysis of EU countries based on business digital readiness, year 2021



Source: Authors based on data from the Eurostat database.

Both dendrograms show good separation and relatively even inclusion of countries into each potential cluster. In both cases, there is an evident formation of three top clusters containing many countries on the higher level. However, it is more useful to get more refined results with a higher number of clusters. First, a solution with 10 clusters has been used (Table 4). Based on the results of the Calinski and Harabasz index and in line with our aims, five main clusters at the higher level have been identified. These clusters are further examined (Table 5). When considering the five main clusters, the crucial differences between the years 2019 and 2021 begin to show up. The first cluster is expanded from 4 to 6 countries. Sweden and Malta joined this group of countries

from the previous second cluster, which was formed in 2019. The third cluster before the pandemic was divided into two separate clusters, and Estonia was included in the different clusters. Three countries out of this cluster formed a new second cluster (Romania, Bulgaria, and Hungary), and another three countries (Greece, Latvia, and Cyprus) created a third cluster during the pandemic. The results are rather interesting. Some of the top-performing countries (Clusters I and II) are closer in terms of digital readiness, and low-performing countries (in Cluster III) are starting to differentiate from each other into separate clusters during the pandemic. There are also some minor changes in clusters IV and V. A few countries have been swapped between clusters. However, the core members of these clusters remain the same. Czechia, Germany, Slovenia, Luxembourg, and Austria are still included in Cluster IV. Spain, Portugal, France, Italy, Slovakia, and Poland have formed Cluster V before as well as during the pandemic.

Table 4
Clustering of countries based on their digital readiness in 2019 and 2021; an initial solution with 10 clusters

Cluster	Clustering at a lower level: 10 clusters (More fragmented)	
	2019	2021
I.	Belgium, Denmark, Finland	Belgium, Denmark, Finland
II.	Netherlands	Sweden, Malta, Netherlands
III.	Sweden, Ireland, Malta	Romania, Bulgaria, Hungary
IV.	Romania, Bulgaria, Hungary, Latvia	Greece, Latvia,
V.	Greece, Estonia	Cyprus
VI.	Cyprus	Czechia, Croatia, Slovenia
VII.	Czechia, Germany, Slovenia, Lithuania	Germany, Austria, Luxembourg
VIII.	Luxembourg, Austria	Ireland, Estonia
IX.	Spain, Portugal, France, Italy	Spain, Portugal
X.	Slovakia, Poland, Croatia	France, Italy, Poland, Slovakia, Lithuania

Source: Authors based on data from the Eurostat database

Table 5
Clustering of countries based on their digital readiness in 2019 and 2021; 5 cluster-solution

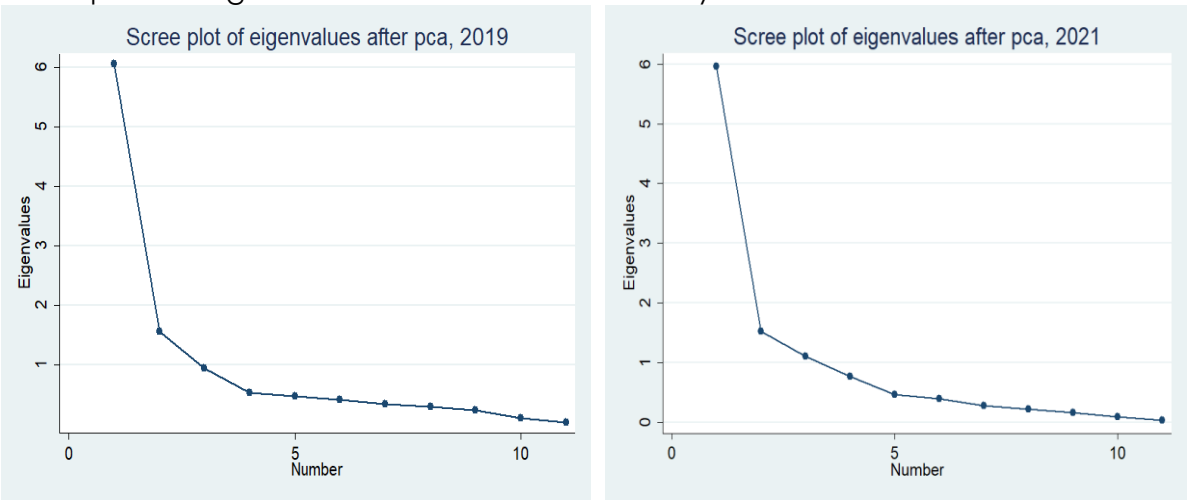
Cluster	Clustering at a higher level: 5 clusters (Less fragmented)	
	2019	2021
I.	Belgium, Denmark, Finland, Netherlands	Belgium, Denmark, Finland, Sweden, Malta, Netherlands
II.	Sweden, Ireland, Malta	Romania, Bulgaria, Hungary
III.	Romania, Bulgaria, Hungary. Latvia, Estonia, Greece, Cyprus	Greece, Latvia, Cyprus
IV.	Czechia, Germany, Slovenia, Lithuania, Luxembourg, Austria	Czechia, Croatia, Slovenia, Germany, Austria, Luxembourg, Ireland, Estonia
V.	Spain, Portugal, France, Italy, Slovakia, Poland, Croatia	Spain, Portugal, France, Italy, Poland, Slovakia, Lithuania

Source: Authors based on data from the Eurostat database

The next part of the analysis describes the individual clusters in more detail. The PCA is used to achieve a more straightforward interpretation of the results. It identifies two

principal components explaining most of the variability in all eleven variables. Two separate PCAs for both years have been applied. Figure 4 shows scree plots representing the decrease in eigenvalues for each number of components resulting from both PCAs. In both cases, two principal components have been used to get results that can be shown in two-dimensional space.

Figure 4
Scree plots of eigenvalues based on the PCA for years 2019 and 2021



Source: Authors based on data from the Eurostat database.

The basic characteristics of both components are shown in Table 6 and Figure 5. Both principal components collectively capture 69% (2019) and 68% (2021) of variability. This means that these components can be used to capture the main essence of overall business digital readiness, as previously explained by eleven variables.

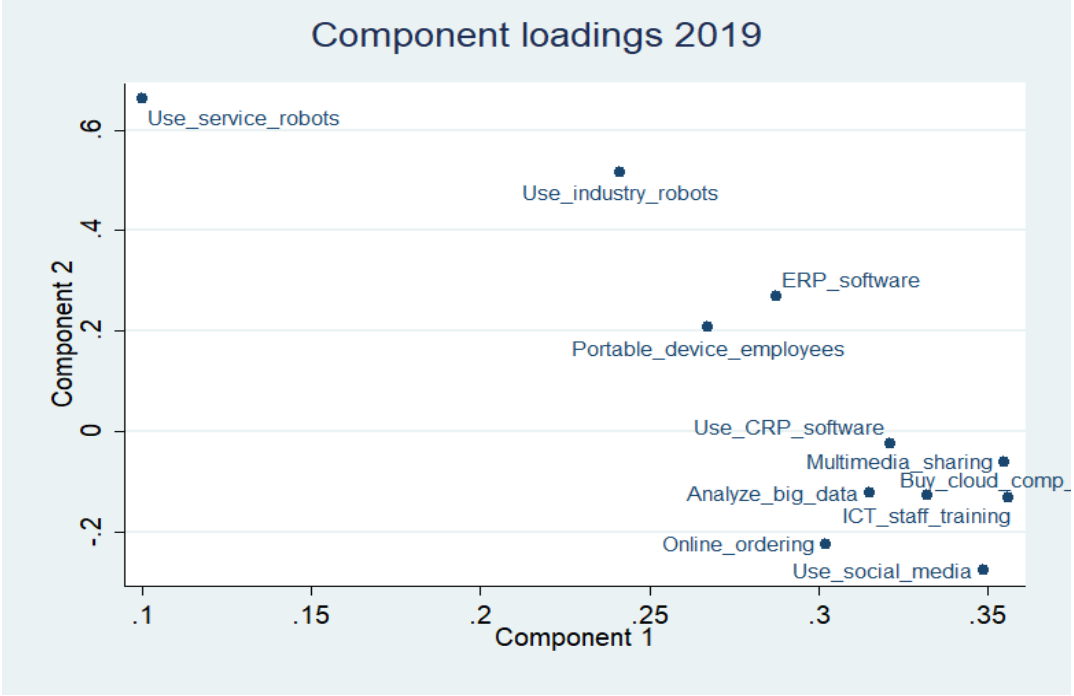
Table 6
Characteristics of the two principal components of digital readiness created by PCA

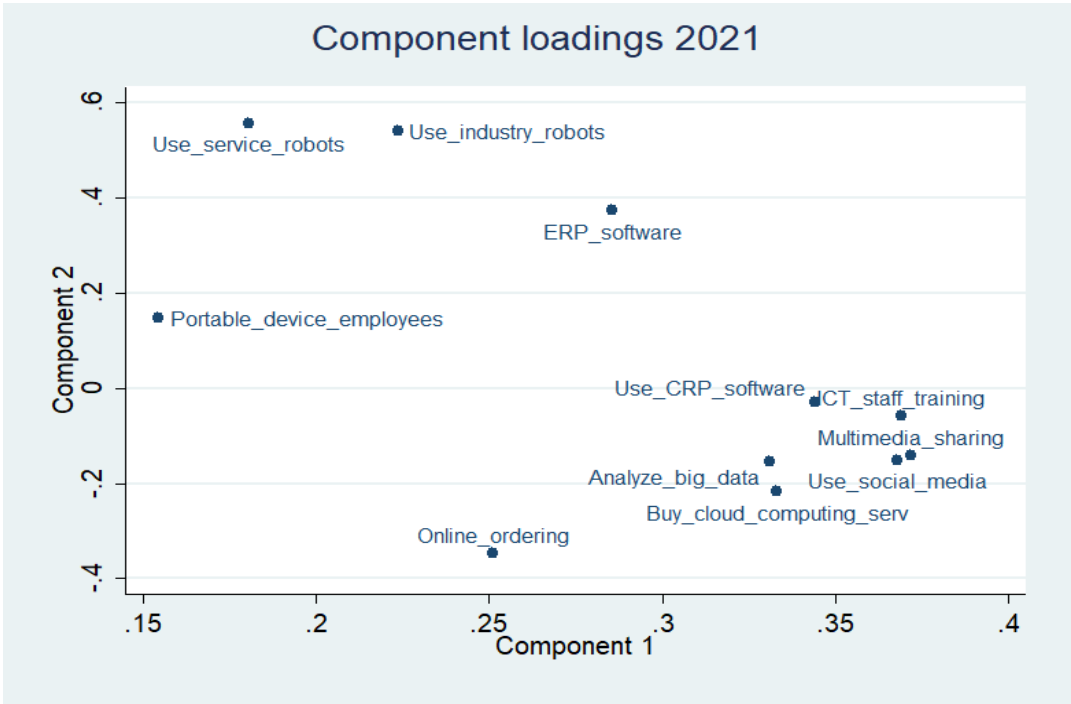
	2019			2021		
	Eigenvalue	Proportion	Cumulative	Eigenvalue	Proportion	Cumulative
Component 1	6.051	0.55	0.55	5.965	0.54	0.54
Component 2	1.563	0.14	0.69	1.52693	0.14	0.68

Source: Authors based on data from the Eurostat database.

More specific component loadings can be seen in Figure 5. Component 2 contains mostly information on the usage of robots in services and industry and, to some extent, also the utilisation of ERP software and portable digital devices for employees. The variables included here mostly express firms' status in automation, robotisation, digital transformation of business processes, and tools for remote work. Hence, this component is focused on processes within the firm and robotisation. Component 1 captures, to the greatest extent, the other 7 variables representing other aspects of business digital readiness, such as the use of digital technology, social media, multimedia sharing, and the possibilities of online ordering. This component is focused on digital transformation with respect to customer and business-to-customer relationships.

Figure 5
Components loadings for both principal components for the years 2019 and 2021



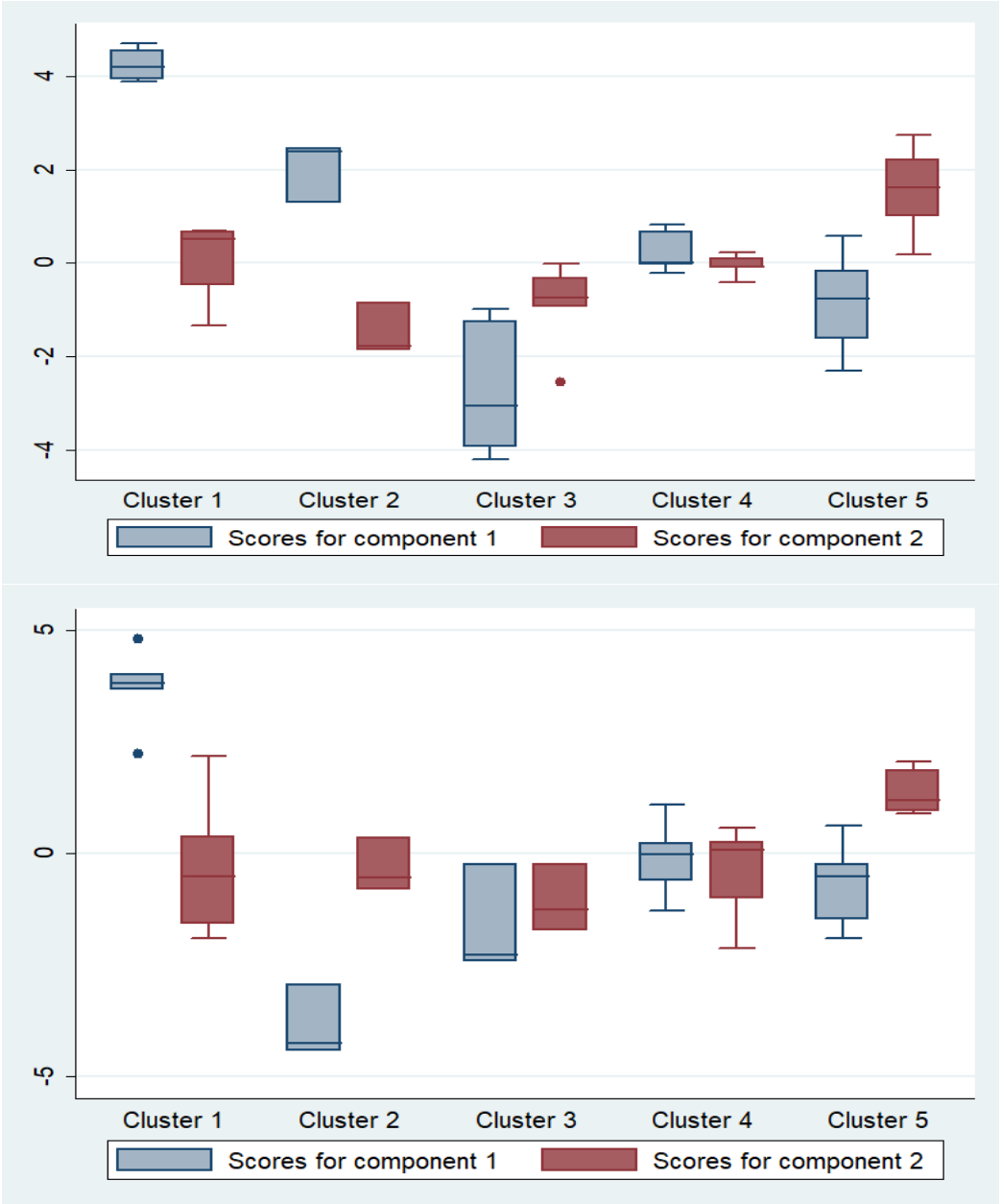


Source: Authors based on data from the Eurostat database.

The distribution of component loadings is similar in both years. Hence, there are two rather distinct principal components depicting slightly different problems related to digital transformation in firms. They also allow us to describe the characteristics of the five main clusters formed by cluster analysis as well as identify the main differences before and during the pandemic. The average scores for both components achieved in each of the clusters have been further investigated. Higher scores mean a better level of business digital readiness in the countries in the cluster. The results are

graphically represented by boxplots, which show median values together with the quartile distribution of values within each cluster (Figure 6).

Figure 6
Boxplots showing the characteristics of five clusters – component scores in 2019 and 2021



Source: Authors based on data from the Eurostat database.

A more detailed explanation of the results is shown in Table 7. Countries classified into the first cluster reach the highest scores with respect to component 1. This means that they are leaders in business digital transformation. This is especially true when considering e-business tools and business-to-customer digitalisation. On the contrary, countries included in the fifth cluster reach the leading position in component 2, which is mostly related to automation, robotisation, and digitalisation of internal processes. The leadership of both clusters in their dominant areas stayed the same before as well as during the pandemic. The problematic cluster is cluster number three. It had the

lowest level of digital readiness before the pandemic. After the pandemic, it split into two clusters. Greece, Latvia, and Cyprus slightly improved their performance and created a new cluster. Moreover, Estonia made it into a significantly better cluster (cluster 4). However, Romania, Bulgaria, and Hungary stay in the cluster with the lowest level of digital readiness.

Table 7
Summary of scores achieved by clusters in relation to both components

	2019	Component 1	Component 2	2021	Component 1	Component 2
I.	Belgium, Denmark, Finland, Netherlands	Very high level with small differences within the cluster	Slightly above the average	Belgium, Denmark, Finland, Sweden, Malta, Netherlands	Very high level	Average level with rather significant differences within the cluster
II.	Sweden, Ireland, Malta	High level	Rather low level	Romania, Bulgaria, Hungary	Very low level	Average
III.	Romania, Bulgaria, Hungary. Latvia, Estonia, Greece, Cyprus	Very low level with rather significant differences within the cluster	Average level	Greece, Latvia, Cyprus	Slightly under the average with rather significant differences within the cluster	Average level
IV.	Czechia, Germany, Slovenia, Lithuania, Luxembourg, Austria	Average level with small differences within the cluster	Average level with small differences within the cluster	Czechia, Croatia, Slovenia, Germany, Austria, Luxembourg, Ireland, Estonia	Average level	Average level
V.	Spain, Portugal, France, Italy, Slovakia, Poland, Croatia	Lower level with rather significant differences within the cluster	High level with rather significant differences within the cluster	Spain, Portugal, France, Italy, Poland, Slovakia, Lithuania	Average level	High level with rather small differences within the cluster

Source: Authors based on data from the Eurostat database.

The last part of our analysis captures the enablers of remote work in more detail. Based on the available data, it examines the measures that companies took to enable remote work during the pandemic. These measures are closely related to the usage of digital tools such as remote access to information, remote meeting software, and ICT systems. The situation was compared among all EU member states (see Table 8). In this case, the data is available only for companies with 10 or more employees. Hence, small enterprises are excluded from this analysis. Firstly, the focus is on the share of companies with the increased share of employees who have remote access to e-mails. On average, almost 33% of enterprises increased the number of these employees, and 13% of enterprises introduced this measure solely due to the

pandemic. The effect of the pandemic on this type of measure was the highest in Malta, Austria, and Cyprus and the lowest in Hungary, Lithuania, and Latvia.

Table 8
The share of remote work-related measures introduced by firms and the effect of the pandemic

	Enterprises that have increased the % of persons employed having remote access to its e-mail (% of enterprises)		Enterprises that have increased the % of persons employed having remote access to the ICT systems of the enterprise other than e-mail (% of enterprises)		Enterprises that have increased the number of remote meetings (e.g. via Skype, Zoom, MS Teams, etc.) (% of enterprises)	
	For any reason	Fully due to Covid	For any reason	Fully due to Covid	For any reason	Fully due to Covid
EU (27)	**32.80%**	**13.00%**	**32.70%**	**14.60%**	**50.1%**	**30.5%**
Belgium	39.70%	13.30%	43.50%	18.10%	67.6%	45.9%
Bulgaria	17.20%	8.60%	14.70%	8.50%	23.3%	13.6%
Denmark	18.60%	NA	23.20%	NA	67.6%	NA
Germany	41.70%	15.10%	38.70%	15.40%	54.1%	30.0%
Italy	30.80%	13.60%	32.60%	16.10%	43.9%	27.1%
Cyprus	35.70%	16.90%	33.10%	16.20%	54.4%	31.4%
Latvia	20.60%	7.70%	19.40%	8.90%	32.6%	19.0%
Lithuania	11.80%	6.10%	11.70%	6.60%	40.6%	23.7%
Luxembourg	33.40%	NA	31.70%	NA	50.9%	NA
Hungary	16.90%	2.60%	16.40%	2.90%	37.0%	18.5%
Malta	55.50%	22.80%	57.60%	27.90%	76.1%	37.6%
Netherlands	42.20%	15.30%	42.40%	17.30%	70.3%	48.1%
Austria	38.20%	20.70%	37.50%	21.90%	56.3%	43.2%
Poland	18.10%	9.90%	20.60%	13.50%	29.4%	22.8%
Portugal	29.80%	9.30%	27.10%	10.50%	47.3%	29.4%
Slovenia	24.20%	6.40%	24.60%	8.00%	48.4%	27.8%
Slovakia	24.60%	8.20%	28.60%	10.90%	41.8%	18.9%
Finland	31.30%	12.00%	31.30%	13.20%	78.7%	48.5%
Sweden	24.60%	8.20%	31.60%	12.30%	71.1%	46.4%

Note: Enterprises with fewer than 10 employees have been excluded from the sample.
Source: Authors based on data from the Eurostat database.

Next, the usage of other remote ICT systems other than email has been examined. The share of firms that adopted this measure is very similar to the previous one. Some enterprises have made this change fully due to COVID-19. More than 57% of enterprises in Malta increased their usage of remote ICT, which had the highest value in the EU. More than a quarter of them did it fully due to COVID-19. In terms of the direct effects of the pandemic, Malta is followed by Austria, Belgium, and the Netherlands. Hungary and Lithuania are again placed on the other side of the ranking.

Finally, the frequency of remote meetings via online team collaboration tools (such as Skype, Zoom, or MS Teams) has been analysed. This is where the most significant changes happened. Moreover, they are largely caused by the pandemic alone. Every second enterprise in the EU has increased the number of online meetings and reported that they increased them fully due to the pandemic.

This time, Finland had the highest increase, followed by Malta, Sweden, and the Netherlands. More than half of the enterprises in Finland, Sweden, and the Netherlands attributed the change to the COVID-19 pandemic. Bulgaria, Poland, Latvia, and Hungary reported a significantly lower increase in online meetings. The most important findings of the paper are briefly summarised in Table 9.

Table 9
Shortened summary of the most significant results

Research questions	Results	Research hypotheses	Results
RQ1	In general, digital readiness of companies increased significantly during the pandemic. However, stagnation (or a slight decrease) in some indicators (big data analytics and ICT trainings) has been also found.	**H1**	Based on the results, H1 cannot rejected (can be confirmed).
RQ2	There were some significant changes during the pandemic. However, countries that performed the best before the pandemic remain in the top-performing cluster. Some countries that had recorded unsatisfactory results managed to significantly improve during the pandemic (e.g., Estonia, Latvia, Lithuania). However, the three worst-performing countries (Romania, Bulgaria, and Hungary) are still classified in the same cluster even during the pandemic.	**H2**	Based on the results, H2 cannot be rejected (can be confirmed). Significant changes in the allocation of countries into the clusters are evident.
RQ3	Some significant difference in cluster characteristics have been found. Most clusters improved in both dimensions (component 1 and component 2) of digital readiness during the pandemic. In most cases, the heterogeneity within individual clusters increased slightly during the pandemic. On the other hand, the difference among the clusters appeared to be smaller during the pandemic.	**H3**	Based on the results, H3 cannot be rejected (can be confirmed).
RQ4	Significant change towards greater use of digital communication technologies to enable remote work has been found. The most significant change was evident in the case of online meetings via digital platforms. In most cases, this change was implemented exclusively because of the pandemic. The greatest increase in the use of digital technologies to enable work was found in Malta, Austria, Finland, Sweden, and Cyprus.	**H4**	Based on the results, H4 cannot be rejected. The share of companies that implemented the measures to enable remote work through digital technology significantly increased.

Source: Authors.

The results are presented in relation to the stated research questions and the research hypotheses. All four research questions have been examined in the paper, and our results helped us draw conclusions and test research hypotheses.

Discussion

The processes of digital transformation in business appear to have been accelerated during the COVID-19 pandemic. Our results show important changes in the usage of selected digital technologies and measures adopted to support remote work and the digital transformation. The shift to e-commerce and remote work is evident, which is reflected in the increased usage of cloud computing services, online ordering, and portable devices in most of the EU countries. In these and many other aspects, pandemics really seem to act as disruptive forces that accelerate the adoption of digital transformation, as reported by Döhring et al. (2021). Social distancing policies stimulate the introduction of new technologies, which enables the involvement of businesses in the digital economy, as previously argued by Ganichev and Koshovets (2021). However, several exceptions have been found as well. There has been no significant increase in the use of service robots, and there has been a slight decrease in the application of big data analytics. These technologies are still relatively new and costly. This can be one of the reasons why firms did not invest in them during pandemic times. There are still evident challenges and barriers to the implementation and usage of big data analytics (Kashyap, 2019) and service robotics (Hudson et al., 2017).

The classification of countries into clusters based on their business digital readiness shows similar partners, as reported previously by Kinnunen et al. (2019) or Borowiecki et al. (2020). Our results show rather significant differences in the digital transformation of businesses in EU countries. In general, firms in the eastern and southern parts of the EU are lagging other EU countries. This is in line with some other studies. For example, Hunady et al. (2022) found a significantly lower level of digital readiness for business in newer member states and southern countries of the EU. Even though there are only a very small number of studies devoted to clustering countries based on their digital readiness at the firm level, their results can still be used for comparison with ours.

The pandemic appears to have changed the classification of countries into clusters. The most significant changes have been found in countries with a previously relatively low level of business digital readiness. For example, Estonia makes a significant step forward. It was placed in a much better group during the pandemic than before it. This result is also supported by the findings of Härmand (2021), who argues that Estonia used political momentum during the pandemic to start fundamental changes supporting digital transformation. These changes include legislation for remote notarial transactions, online annual meetings, and digital infrastructure. On the other hand, the countries with lower digital readiness (Romania, Bulgaria, and Hungary) remain in the same cluster even during the pandemic. These countries are usually placed at the end of the digital rankings. Kovács et al. (2023) showed that Hungary, Bulgaria, Romania, and Poland are ranked the lowest based on the degree of integration of digital technologies in the EU. Interestingly, the results indicate that the difference among the clusters appeared to be smaller during the pandemic compared to the situation before. This may be due to public financial and non-financial support as well as demand shocks during the pandemic. The economic reasons for the mentioned development could be further investigated. This research problem could be further examined in future research.

There are several other limitations of our study. First, it would be interesting to compare the results with the new data after the end of the intense pandemic. When these data are available to a sufficient extent, an even more comprehensive comparison will be possible. Moreover, our approach captures only differences while considering two points in time. This is since cluster analysis is usually not suitable for capturing dynamic changes. However, there are some more advanced approaches, such as KmL clustering for longitudinal data developed by Genolini and Falissard

(2011), that are currently used mostly in other fields than economics. This method can capture dynamic trends in digital readiness and perform clustering on panel data. With the application of such methods, it would be possible to further extend our findings in future research.

Our research was also focused on examining the changes in remote work and measures taken by businesses to increase the usage of digital tools enabling remote access. This problem is seen as one of the main pandemic-related phenomena, as reported by Adžić and Al-Mansour (2021). Our results show the positive effect of the COVID-19 pandemic on these types of measures. Firms with ten or more employees considerably increase the share of employees with remote access to e-mail as well as to other ICT systems. More than a third of these changes were caused exclusively by the COVID-19 pandemic. Moreover, every other company in the EU has significantly intensified the remote meeting via digital platforms. More than 30% of all enterprises stated that these measures have been fully adopted due to the pandemic. These results are fully in line with Kraus et al. (2020). They found that most firms introduced new work-from-home policies and enabled remote work during the pandemic.

Conclusion

The paper brings some new findings on digital transformation in business during the pandemic. These findings are based on empirical evidence from EU countries. They confirm the fact that most companies have increased their pace of digital transformation in general. This is especially true for customer-focused digital tools and enablers of e-business. On the other hand, in some technologies, such as big data analysis and the implementation of service robots, signs of stagnation or even a decline have been found. The countries have been classified based on their digital readiness for business into rather homogenous groups. This classification was provided before and during the pandemic. Some significant differences between both periods have been found. Belgium, Denmark, Finland, Sweden, Malta, and the Netherlands form a cluster of countries with the highest overall digital readiness. This is especially true in the case of customer-oriented digital tools. On the other hand, countries like Spain, Portugal, France, Italy, Poland, Slovakia, and Lithuania seem to be dominant in the robotisation and digitalisation of internal business processes. Some significant shifts between clusters have been found. Estonia, Malta, and Sweden are the three countries with the most significant improvements. The original cluster of countries with the lowest level of digital readiness has been split into more clusters. However, the worst-performing countries (Bulgaria, Romania, and Hungary) remain to be included in the same cluster. The EU policies to support digital transformation should be primarily focused on these countries to fill the gap. Even though the worst-performing countries are still significantly struggling to improve, our results also suggest that the differences among clusters tend to shrink slightly during the COVID-19 pandemic.

The paper also examines the response of companies to the pandemic in the form of remote work-related measures. In this area, companies in Malta, Finland, Sweden, and the Netherlands did the most during the pandemic. Every second firm in the EU has increased the number of online meetings, and more than half of them introduced this measure only due to the pandemic. Similarly, more than 13% of firms adopted new measures for employees' remote access to email and other ICT systems exclusively due to the pandemic.

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