

# Acceleration of the digital economy as support for sustainable development

*Lenka Kuhnová\**, *Petra Szaryszová*, and *Martin Bosák*

University of Economics in Bratislava, Košice, Slovak Republic

**Abstract.** Leading companies are increasingly using digital technologies to transform their business models with the aim of better solution of social challenges. However, there is not enough management data on whether it is a positive driver influencing innovation for both the economy and society. Research on the digital economy continues to develop but is limited to one country or area. From a bibliometric retrospective review, the paper deals with the current discussion on the alignment between sustainability challenges and innovation procedures based on the digitization of the economy. This study used bibliometric techniques using the VOSViewer program and the search results analysis function of the Springer database. This study analyzed 40,932 scientific documents published from 1841 to 2023. We further investigated the support of digital transformation and sustainability in EU countries by beta convergence and PCA analysis. The results confirm the convergence of EU countries and progress in the implementation of digital technologies in the field of digital transformation of sustainable development. The EU actively supports digital transformation and the Digital Single Market through various initiatives and policies.

## 1 Introduction

Digital technologies represent a functional resource for achieving goals at the corporate or national level. Issues of support and usability of the progress of digital transformation and sustainability represent the current discussions of major management consulting companies [1,2,3,4] and many governments [5,6,7]. Although the exponential progress of artificial intelligence and machine learning is evident, sustainability is nevertheless one of the fastest growing phenomena, but it is still an under-discussed area in connection with digital technologies.

Digitization also creates economic forces that make it easier for companies to expand. Digitization makes market entry easier, because companies that can capture and aggregate data from different sectors can discover and exploit new kinds of synergies. Such a data-driven market entry leads to the expansion of the scope of digital platform firms.

### 1.1 Theories of cost management in the digital environment

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\*Corresponding author: [lenka.kuhnova@cuba.sk](mailto:lenka.kuhnova@cuba.sk)

Within the framework to clarify the complexity of the application of digital transformation in the sense of sustainability, in the paper we analyze the current scientific and professional literature on the relationship between the digitalization of the economy and sustainability.

Strategic sustainability is a key part of the successful functioning of companies. Modern economic theories define a digital product as a good that can be procured at zero cost. In the digital environment, the cost of products is lower even with respect to geographical distance, thus increasing their potential range and quality.

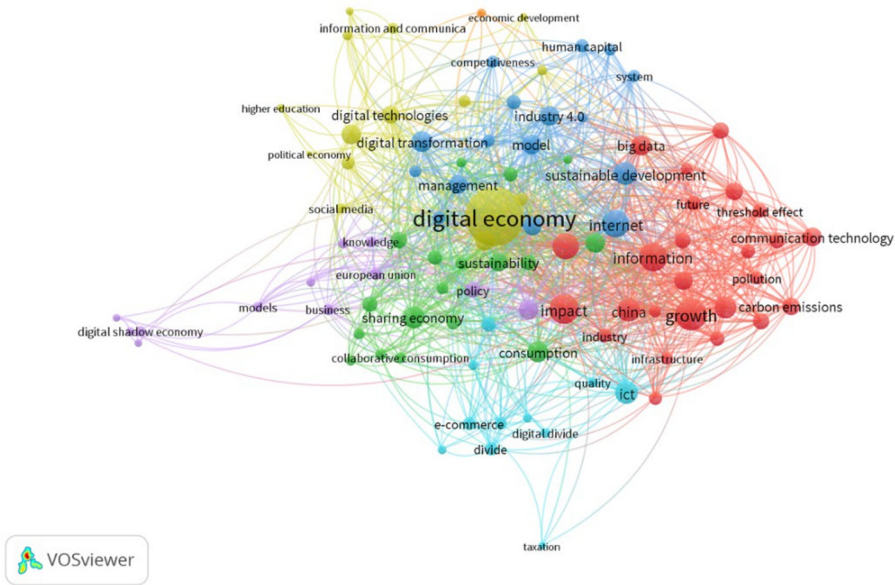
Theoretical studies of cost changes are based on a set of well-established economic models. Already in the literary sources of Varian [8] from the late 1990s and early 21st century, it directly followed older models in which he identified shortcomings with simple models and thus developed extended models of cost minimization, where aspects of the digital context are indicated. Other authors have also emphasized the role of cost reduction for the digital economy, for example Shapiro, Varian and Smith, Bailey, and Brynjolfsson [8, 9, 10].

Since the article by Ellison and Ellison [11] discussing the issue of diminishing costs, the digital economics literature has grown to contribute to the economics of public goods, organizational economics, finance, urban economics, labor economics, development economics, health economics, political economy, media economy, public finance, and international economy. In this sense, we perceive the digital economy as a way of thinking that touches many areas of the economy. In addition to being applied in many areas, these cost shifts have changed many aspects of the economy.

Companies can narrow the boundaries of their scope if they can digitally connect to remote agents and resources to obtain data from them that they can analyze and exploit. We can therefore expect the emergence of new asset-light companies that focus on data collection, data aggregation and analysis, requiring little need to invest in physical resources.

Khalid-Naumova [12] investigated the possibilities of digital transformation through supply chain management, driven by the constantly changing business environment and customer requirements. Other studies have identified that the level of digitization of the economy and society depends on the overall level of human development and GDP of the country.

We conducted a bibliometric review to identify the growing interest of various groups of international scientists in various fields, especially in the field of digital economy, environmental science and informatization. Through research, we found that over the past three decades, the most influential journals and authors of this literary base of international scope have continued to grow. As mentioned earlier, we conducted a common word analysis to identify current outbreaks in the digital economy literature and performed a cluster analysis of keywords (Fig. 1).



**Fig. 1** Cluster analysis of key words of the researched issue.

Source: own processing

In the first cluster, marked in yellow, the main keyword is "digital economy" and those most often referred to as "digital transformation", "digital technologies", "political economy" and "information and communication", indicating that the spread ICT requires acquiring and teaching digital skills.

Many argue that ICT tools are essential for the development and growth of countries' economies. The red-marked cluster is characterized by the perceived basic idea that is associated with the term digital economy, namely pollution, growth, the influence of industry, information, big data, etc. The number of relevant studies is higher in this cluster and associated with the keyword "China". In this cluster, as well as in green and dark blue, the concepts of sustainable development and Industry 4.0 can be researched. We can claim that the economy of countries must meet not only the criteria of competitiveness, but also of sustainability. The digital economy must be taken into consideration when designing national strategies to achieve economic and social progress.

Considering the impact of digitization on business performance, we can state that it is essential to develop human capital, integrate digital technologies and have extensive and solid digital coverage. In the purple cluster, there is a close connection with the keyword "European union", as monitoring the development of the digitization of economies and related terms such as "digital shadow economy", "business", "models" and "knowledge" is important for EU member states. The light blue cluster contains the most frequently occurring keywords that are related to tax issues and consumer behavior, while also having a significant impact on the "digital economy".

## 2 Materials and Methods

From a bibliometric retrospective review, the study examines research trends in the field of the digital economy on an international scale. To review the literature that analyzes relationships, we consider it most appropriate to perform a bibliometric analysis. To

examine keywords, we used the freely available bibliometric software VOSviewer for this purpose.

VOSviewer software uses colors to distinguish between clusters identified during analysis. We interpret the relationship network between relevant keywords as the size of the points, which represents the frequency of occurrence, its thickness of the lines connecting the points represents the frequency of co-occurrence of each keyword, and the distance between individual points represents the strength of the relationship between the keywords. The data in this review study were obtained from the Springer index database. The Springer index database was chosen as a source in this study due to its better clarity in the areas of the digital economy and is used to create a database for systematic research reviews.

The aim of the research is to use statistical-mathematical methods to look for evidence of the digital development of the member states, through the convergence of the economic, social and, in this case, the digital development of the EU member states for the period 2012-2022. We used  $\beta$  convergence to estimate the cohesion of countries. Beta convergence generally deals with the issue of economic growth and its dynamics. We observe convergence when countries with lower levels of the monitored phenomenon grow faster than countries with higher levels at the beginning of the monitored period. We define the concept of beta convergence in the following equation:

$$y_{i,T} - y_{i,0} = a_1 - b_1 \times y_{i,0} + e_i$$

where  $i$  denotes the ordinal number of the observation (country, region), 0 and T two time points. Beta convergence assumes a positive value of  $\beta$ . Furthermore, if all countries and regions have the same steady state  $a$  and the time is long enough for the countries to "converge" to this steady state,  $\beta = 1$ . The regression coefficient  $\beta$  expresses how much of the difference to the steady state with the countries "on average" managed to eliminate.

We used the method of component analysis (PCA), it is a technique that reduces the number of dimensions in the data and at the same time minimizes the loss of information.

First, we need to standardize the data set to ensure that each variable has a mean of 0 and a standard deviation of 1.

$$Z = \frac{X - \mu}{\sigma}$$

Here,

$\mu$  is the mean of independent features

$$\mu = \{\mu_1, \mu_2, \dots, \mu_m\}$$

$\sigma$  is the standard deviation of independent features

$$\sigma = \{\sigma_1, \sigma_2, \dots, \sigma_m\}$$

Covariance measures the strength of joint variability between two or more variables, indicating how much they vary in relation to each other. We can use the formula to find the covariance:

$$cov(x_1, x_2) = \frac{\sum_{i=1}^n (x_{1i} - x_1)(x_{2i} - x_2)}{n - 1}$$

The covariance value can be positive, negative or zero.

Positive: As  $x_1$  increases, so does  $x_2$ .

Negative: As  $x_1$  increases,  $x_2$  also decreases.

Nulls: No direct association

Step 3: Calculating the eigenvalues and eigenvectors of the covariance matrix to identify the main components.

Let A be an  $n \times n$  square matrix and let X be a nonzero vector for which:

$$AX = \lambda X$$

for some scalar values of  $\lambda$ , then  $\lambda$  is known as the eigenvalue of the matrix  $A$  and  $X$  is known as the eigenvector of the matrix  $A$  for the corresponding eigenvalue.

It can also be written as:

$$AX - \lambda X = 0$$

$$(A - \lambda I)X = 0$$

where  $I$  is an identity matrix of the same form as the matrix  $A$ . And the above conditions will be satisfied only if it is non-invertible (i.e. a singular matrix). It means

$$|A - \lambda I| = 0$$

From the above equation, we can find the eigenvalues of  $\lambda$  and therefore the corresponding eigenvector can be found using equation

$$AX = \lambda X$$

The method works by rotating the axes in such a way that there is more variance along them, and then transforming the data into principal component values, also known as scores. These principal components serve as the new axes, and the PC scores represent the projections of the original dimensions onto the new axes. PCA prioritizes the principal components based on importance, with PC1 being the component that explains the most variance in the data, followed by PC2 etc. Considering only the first few principal components, such as the first two, can explain a significant percentage of the variance in the data. This allows high-dimensional data to be displayed on a two-dimensional graph.

### 3 Results

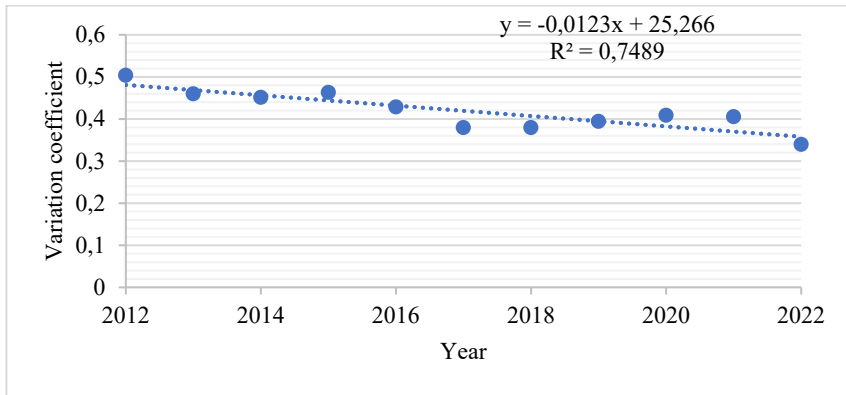
Companies that accept orders online represent an important and ever-growing segment of the business world. Their presence is more than just a modern trend, as they allow businesses to expand their markets and reach a wider customer base. Businesses that accept orders online can include a variety of industries such as retail, wholesale, services, hospitality, tourism and many more. Currently, it is estimated that more than 1 % of companies take orders online. However, the percentage of companies that take orders online could be much higher as more and more companies decide for an online presence.

Online sales platforms and e-commerce are becoming a necessity for companies to stay competitive. These companies often create websites or mobile applications where customers can browse and purchase their products or services. They offer various payment methods such as credit card payments, internet banking, digital wallets and other.

The benefits of taking orders online for businesses are obvious. Among the most important are the increase in customer accessibility, 24/7 operation regardless of place and time, expansion of the customer base and the possibility of better tracking and analyzing sales. In addition, online sales can help businesses increase efficiency and reduce operating costs, for example through order automation and digital warehouse management.

Customers also benefit from online shopping. They can shop from the comfort of their homes, compare prices and reviews, and have access to a wider range of goods and services. It is important to emphasize that companies that accept orders online must also have thorough security of online payment transactions and protection of customers' personal data. Online sales also include providing reliable customer support via e-mail, chat, or phone.

All in all, companies that take orders online have a significant role to play in today's digital world (Fig. 2). With a growing number of customers preferring to shop online, the percentage of businesses that will accept orders online is expected to continue to grow.



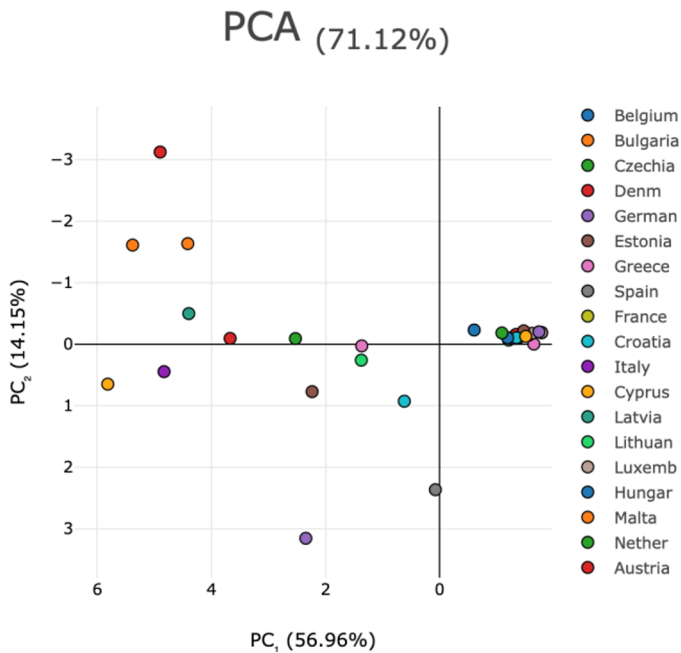
**Fig. 2.** Companies that accepted orders online (at least 1 %) - % of companies.

Source: own processing

The indicator of companies that accepted orders online in EU countries represents, within the measurement of sigma convergence, the correlation coefficient is high, so it can be assessed that this condition is met. As already characterized, the decrease of interregional disparities is very slow. The correlation coefficient is higher in this case. The critical value at the  $\alpha = 0.05$  significance level is 0.7622, and therefore convergence is demonstrable.

Companies with online platforms do not only take advantage of modern digital infrastructures such as the Internet, the cloud and global mobile connectivity. They also take advantage of the behavioral habits of billions of users who continuously (and often unknowingly) generate data by connecting to these platforms through their digital devices every day to use digital services. In turn, this output data becomes a key resource that platform companies use to further improve digital services offered, develop new services, and enter new markets.

New digital technology and the Internet have drastically reduced the costs of search, entry, transport, and reproduction, unlocking enormous potential for increased economic efficiency [13]. At the same time, these changes in costs bring new challenges for the organization of markets, especially because of their profound impact on the role of platforms, the value and protection of innovation, and the trade-off between companies' use of data and consumer privacy. In this paper, we explore insights from some recent studies on opportunities and challenges in the digital economy, particularly issues related to platforms, innovation, and consumer data, and discuss how well-designed policies can improve market performance. The support of digital transformation and sustainability in EU countries by beta convergence and PCA analysis was investigated (Fig. 3).



**Fig. 3.** Share of the ICT sector in GDP

Source: own processing

Most of the Member States operate within digital technologies on the right side of the main X-axis. Romania, Lithuania, the Netherlands, are slightly behind in network connectivity, but do very well in the digital field in terms of the share of the ICT sector in GDP. This is not the case for Spain and Poland, which are on the left side of the X-axis, i.e. among the least developed and perform very unfavorably. The share of ICT in GDP is above average in cluster countries such as Finland, Greece, Serbia, UK, Portugal, Austria, Poland, Hungary, and the Czech Republic and Slovakia are not far behind.

The third group mainly includes countries that usually have poor results in the field of digital technologies, although the infrastructure there is significant Montenegro, Bulgaria, Cyprus.

Sweden and Liechtenstein have surprisingly low values for ICT use, although they are among the countries implementing digital technologies at the enterprise level in sufficient quantity.

## 4 Conclusion

According to the results, the number of international publications on the digital economy, as well as maps and visual trends, is increasing every year. Convergence in the field of digital transformation of sustainable development is demonstrated within the EU. The EU actively supports digital transformation and the Digital Single Market through various initiatives and policies that aim to reduce the digital divide between Member States and ensure that all countries and sectors have access to digital technologies and digital services.

The European Commission has adopted several strategies and programs that focus on digital transformation and the support of digital technologies. These strategies include, for example, the Digital Age Strategy for Europe, which sets goals and measures for the development of digital technologies, digital skills, and digital services across the EU.

Another important document is the European Digital Agenda, which deals with issues such as artificial intelligence, cyber security, digital education and more.

These and other EU measures are aimed at reducing the digital divide between member states and supporting digital transformation in all sectors. The aim is to ensure that all EU countries have equal opportunities in the digital environment and that digital technologies contribute to economic growth, competitiveness, and support for the sustainable development of the EU.

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