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# ANALYSIS OF DISPARITIES IN THE USE OF INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) IN THE EU COUNTRIES*

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**Abstract.** In general, the digital economy plays an important role in the achievement of sustainable economic development, creation of a favourable investment climate, increase in income, and improvement of the welfare of the population. The digital economy is a very broad concept and it refers to the digitalization of the economy as a whole. However, it is based on infrastructure and the intensity of the use of Internet technology. To what extent do the EU countries differ in terms of availability and use of Internet technology? What trends occur in the dynamics of disparities in the level of use of Internet technology in the EU countries? In relation to the abovementioned questions, it is necessary to monitor and analyse the level of use of Internet technology in various EU countries in dynamics. The purpose of the research is to assess the level of use of Internet technology in the EU as a basis of the digital economy, as well as to assess disparities in the use of Internet technology in the EU in the period 2012-2020.

**Keywords:** EU; Internet use index; disparities; ICT

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## 1. Introduction

Researchers have increasingly focused on the impact of information and communication technology (ICT) on national economies (Rozite et al., 2019, Al-Busaidi, 2020; Petric et al., 2020; Cheng et al., 2021). ICT has rapidly been integrated not only into people's daily lives, but also into the daily lives of other economic entities – companies (Karczewska, 2020; Steffen, Erdsiek, 2020), organizations (Dmitrieva et al., 2019), and public administration (Goodridge et al., 2019; Krawczyk, 2020). The Digital Single Market Strategy for Europe stated that the Internet and digital technologies are transforming the lives we lead, the way we work as individuals, in business, and in our communities as they become more integrated across all sectors of our economy and society. With the advent of ICT in the economy, digital transformation has become increasingly important, and, as a result, the traditional economy is being transformed. Since the concept of the digital economy is multidimensional and ambiguous, researchers define and measure it from different perspectives (Van Dijk, 2015; Pietrzak & Ziemkiewicz, 2018; Hushtan, & Danylo, 2021). The role of ITC increases during the COVID-19 Pandemic (Arshad, 2020; Petropoulos, 2020; Chamola et al., 2020; Whitelaw et al.; Ye et. al. 2020).

In recent years, many modern authors have been studying problems of the digital economy (Okrepilov et al., 2017; Batyrbekova et al., Van Deursen, et al., 2018; Van Deursen, et al., 2020; Gaziz et al., 2020; Gladkova et al., 2020; Kravchenko, 2020; Hussain, 2021).

The digital economy is rapidly developing in every country around the world. ICT is believed to make an important contribution to national development, so countries support and develop the growth of the digital economy (Graham et al., 2014; Van Deursen, Van Dijk, 2015; Fernández-Portillo, 2020; Perez-Castro, 2021).

It should be noted that the term digital economy has been used relatively recently, since the 1990s, when the first book that mentions and describes the digital economy was published. In his work "The Digital Economy: Promise and Peril in the Age of Networked Intelligence" in 1995, Don Tapscott interpreted and described the concept of the digital economy and how the digital economy will affect the future. It was the first book to mention and describe how the Internet would change the way we do business today (Tapscott, 1996).

In the digital economy, the Internet is the infrastructure for commerce. Therefore, it can be concluded that the Internet is a prerequisite for the existence of the digital economy. Computers will be used not only as an information management tool but also as a means of communication, comparable with modern social networks. The internet makes it possible to build a new economy based on networked human intelligence (Tapscott, 1996).

In the modern era, the problems of uneven development at the country, regional, and global levels are becoming particularly acute. The price of backwardness and costs for those who did not have time to fit into the new system of the world economy, which is being formed under the influence of globalization, is increasing many times in comparison with the past. The information revolution of the late 20$^{th}$ century made time the most important factor of competition. Analysis of the development of countries and regions, as well as factors that positively influence the smoothing of regional disparities, is an area of increased interest for economists dealing with regional policy issues. A new rise in theoretical debates in the field of neoclassical theories took place in the 1990s, which was caused by the study on the problems of convergence conducted by economists R. Barro and X. Sala-i-Martin in 1990. Sigma-convergence is undoubtedly one of the most common assessment methods in the field of measuring regional disparities. Sigma-convergence illustrates how inequalities between countries and regions evolve in relation to a given parameter (for example, GDP per capita, productivity, etc.). Sigma-convergence is defined as a permanent reduction of regional disparities. In other words, this is a convergence of the levels of development of countries and regions according to the parameter under study, and a decrease in interregional inequality. As for the compatibility of the two types of convergence, there is a number of mathematical evidence that sigma-convergence leads to beta-convergence, however, there is no inverse relationship. That is, if there is convergence

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according to a certain indicator, beta-convergence analysis will not lead to significant results, and in the absence of convergence, beta-convergence analysis is not indicative. Therefore, the practical analysis of beta-convergence reveals only the presence of certain properties in the behaviour of the indicator under study.

The aim of the research is the assessment of the level of Internet technology use, as well as the assessment of disparities in the level of Internet technology use in the EU countries as the basis for the digital economy.

## 2. Methodology

It is difficult to compare the states of objects according to several indicators in different periods simultaneously. Even in one area of indicators describing only one characteristic feature, there can sometimes be several dozens of such indicators. For example, to compare different countries according to a given characteristic feature, it is convenient to represent it in scalar form (Lavriņenko, Lavrinoviča, 2013).

The integral indicator is a scalar obtained from a set of estimates of individual analyzed properties of an object. The integral indicator is a well-known integral property of objects which usually reflects many individual, special properties, a tool for analysis. Particular cases may have different characteristics which are evaluated by different indicators. Certain groups of population, regions, etc. can serve as objects (Lavriņenko, Lavrinoviča, 2013).

To construct an integral indicator, it is necessary to perform the following tasks:

1) to unify the data;

2) to select the most useful primary statistical indicators for diagnostics, i.e. indicators that make up a posteriori lists from a wide set of a priori indicators available in statistical databases;

3) to find the weight coefficients for the selected indicators from the a posteriori list;

4) to combine the selected a posteriori indicators from the list into one integral indicator (Lavriņenko, Lavrinoviča, 2013).

The digital economy indicators available in the statistical databases were obtained in a standardized way, therefore, the indicators were not standardized. All available indicators of the digital economy used in the research are available in databases as a percentage (%).

In order to create an integral indicator, it is necessary to reduce the statistical data to a single form, so that the range of possible measurement values is from 0 to 100. It was calculated according to the following formula:

- indicators that have a positive impact on the digital economy (stimulants):

$$x_{ij}^{'} = \frac{x_{ij} - x_{\min j}}{x_{\max j} - x_{\min j}} * 100,$$

- indicators that have a negative impact on the digital economy (destimulants):

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$$x'_{ij} = \frac{x_{\max j} - x_{ij}}{x_{\max j} - x_{\min j}} * 100,$$

where $x'_{ij}$ – unified indicator's "*j*" value in the EU country "*i*", $x_{\min}$ and $x_{\max}$ — lowest (worst) and largest (best) values of the output indicator in the period under study.

The digital economy indicators were divided into stimulants and destimulants (see Table 1).

**Table1.** Stimulants and destimulants of the Internet technology use indicator in the EU countries.

| No | Digital economy indicator | Unit | Stimulant/ destimulant |
|---|---|---|---|
| 1. | Proportion of companies that use Customer Relation Management software to analyze customer information for marketing purposes. | Percentage of enterprises out of all enterprises, excluding the financial sector (10 and more people employed) | Stimulant |
| 2. | Companies that receive orders online (at least 1%) and make e-commerce sales at least 1% of their turnover. | Percentage of enterprises out of all enterprises, excluding the financial sector (10 and more people employed) | Stimulant |
| 3. | Percentage of households with access to the Internet at home, includes all types of Internet use. | Percentage of households out of all households. | Stimulant |
| 4. | Percentage of households with a broadband Internet connection. | Percentage of households out of all households. | Stimulant |
| 5. | Proportion of individuals who use mobile devices to access the Internet while away from home or work. | Percentage of individuals out of all individuals | Stimulant |
| 6. | Proportion of individuals who have ordered / purchased goods or services via the Internet for private use in the last three months. | Percentage of individuals out of all individuals | Stimulant |
| 7. | Proportion of individuals who use the Internet to order goods or services, last online purchase within 12 months | Percentage of individuals out of all individuals | Stimulant |
| 8. | Proportion of individuals who have used the Internet to communicate with public authorities (in the last 12 months) | Percentage of individuals out of all individuals | Stimulant |
| 9. | Proportion of individuals who have ever used the Internet | Percentage of individuals out of all individuals | Stimulant |
| 10. | Proportion of individuals who regularly use the Internet, frequency of Internet access: once a week (including daily) | Percentage of individuals out of all individuals | Stimulant |
| 11. | Proportion of individuals who use the Internet to participate in social networks (creating a user profile, posting or other contribution on Facebook, Twitter, etc.) | Percentage of individuals out of all individuals | Stimulant |
| 12. | Proportion of individuals who use the Internet to sell goods or services. | Percentage of individuals out of all individuals | Stimulant |

*Source:* developed by the authors based on the Eurostat database

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The abovementioned approach is scalar in the sense that it takes into account the (negative or positive) nature of the impact of the primary statistical indicator on the composite integrated indicator of the Internet technology use and the EU countries, and limits the range of values from 0 to 100 for the comparison between the EU countries (Lavriņenko, 2010).

Although the concept and quantitative methods for assessing convergence were originally developed to study the dynamics of economic growth, they were later extended to the study of the coordination of institutions and other indicators. Empirical studies mainly use two concepts of convergence, which are interrelated but cause different effects of economic policy: β-convergence (Barro, Sala-i-Martin, 1992) and σ-convergence (Sala-i-Martin, 1996a; Sala-i-Martin, 1996b).

According to β-convergence, regions with low absolute values of the indicator under study at the initial period of time are characterised by on average a higher growth rate of this indicator during the process of integration. In order to evaluate β-convergence, growth-initial level regressions are used: $y_i = a + \beta \ln(x_{it}\text{-}T) + e$, where $x_{it-T}$ – an indicator at the point of time preceding the current point of time t at T periods (as a rule, the initial period of integration), β – a coefficient to be evaluated, $y_i$ – average growth rates in i- region over T periods, calculated as $\ln(y_{it})/\ln(y_{it-T})$, e- a random deviation. The value of the β coefficient is an indicator of convergence. If β<0, a high level of the indicator at the initial time period correlate with relatively lower growth rates (Čizo et al., 2018). Unlike β-convergence, σ-convergence presupposes the decrease with time in a standard deviation of the indicator's value which levels the discrepancy between regions. Another indicator that is often used when there is a trend in time series is the relation of a standard deviation to average (variation coefficient). β-convergence (i.e. a quicker growth of indicators in the states with lower values of this indicator at the initial period) does not necessarily lead to the decrease in inequality on the indicator under study, namely to σ-convergence (Barro, Sala-i-Martin, 1991, 1992). It happens when a group of regions with the initially low absolute values of the indicator constantly changes places with the states with the initially higher absolute values of the indicator, although the overall level of gap between these regions is permanent (Sala-i-Martin, 1996a; Sala-i-Martin, 1996b; Barro, Sala-I-Martin, 1991; Barro, Sala-I-Martin, 1995). The authors used the relative indicators of the variation: the coefficient of range and the coefficient of variation. Their calculation is as follows: $K_R = \frac{X_{\max} - X_{\min}}{\bar{x}}$, $(V_\sigma) = \frac{\sigma}{\bar{x}}$ where δ - a standard deviation, $\bar{x}$ - an average value, $X_{max}$ and $X_{min}$– the largest and smallest value of the characteristic in the selection (Čizo et al., 2018; Smirnov et al., 2019).

## 3. Research results

According to the methodology described above, a composite indicator of the Internet technology use in the EU countries in 2012 and 2019/2020 was obtained. As Table 2 shows, Denmark is the leader among the EU countries according to the constructed integral digital economy indicator both in 2012 and 2019/2020. It should be noted that the integral indicator of the Danish digital economy increased from 91.65 in 2012 to 91.91 in 2019/2020.

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**Table 2.** Calculated values of the integral indicator of the Internet technology use and their distribution by quintiles in the EU countries in 2012 and 2019/2020

| EU country | 2012 | 2012 | 2019/ 2020 | 2019/2020 |
|---|---|---|---|---|
| Denmark | 5 | 91.65 | 5 | 91.91 |
| Sweden | 5 | 90.21 | 5 | 87.41 |
| Netherlands | 5 | 80.45 | 5 | 89.03 |
| Finland | 5 | 79.40 | 5 | 79.68 |
| United Kingdom | 5 | 78.89 | 5 | 84.14 |
| Luxemburg | 4 | 76.69 | 4 | 68.08 |
| Belgium | 4 | 62.63 | 4 | 72.98 |
| Germany | 4 | 70.04 | 4 | 71.18 |
| Ireland | 4 | 61.13 | 4 | 71.40 |
| Austria | 4 | 58.14 | 3 | 59.64 |
| France | 4 | 62.41 | 3 | 56.00 |
| Estonia | 3 | 44.61 | 4 | 63.21 |
| Spain | 3 | 41.56 | 4 | 62.13 |
| Malta | 3 | 52.23 | 3 | 61.20 |
| Czech Republic | 3 | 40.41 | 3 | 53.53 |
| Slovakia | 3 | 51.83 | 2 | 44.84 |
| Slovenia | 3 | 46.80 | 3 | 46.60 |
| Hungary | 2 | 35.00 | 2 | 40.46 |
| Croatia | 2 | 32.26 | 2 | 35.59 |
| Latvia | 2 | 37.34 | 2 | 41.17 |
| Lithuania | 2 | 28.41 | 2 | 45.12 |
| Poland | 2 | 30.00 | 2 | 39.55 |
| Portugal | 2 | 28.81 | 1 | 27.83 |
| Cyprus | 1 | 26.54 | 3 | 47.58 |
| Bulgaria | 1 | 10.63 | 1 | 9.15 |
| Greece | 1 | 14,77 | 1 | 24.24 |
| Italy | 1 | 16.46 | 1 | 22.05 |
| Romania | 1 | 5.33 | 1 | 22.29 |

*Source:* Calculated by the authors according to the values of the integrated digital economy indicator in the SPSS programme

The authors applied a cartographic method for the distribution of the EU countries into quintile groups (see Fig.1 and 2). According to the distribution of quintile groups, it can be seen that in 2012 and 2019/2020 there are TOP 5 EU countries with the highest integral indicator: Denmark (91.65 and 91.91), Sweden (90.21 and 87.41), the Netherlands (80.45 and 89.03), Finland (79.40 and 79.68), and the United Kingdom (78.89 and 84.14). The largest increase in the value of the digital economy integral indicator is observed in Cyprus: the integral indicator increased by 21.04 values between 2012 and 2019. The lowest value of the integral indicator is observed in Romania - 5.33 in 2012 and 22.29 in 2019. However, there is also an increase in the value of the indicator.

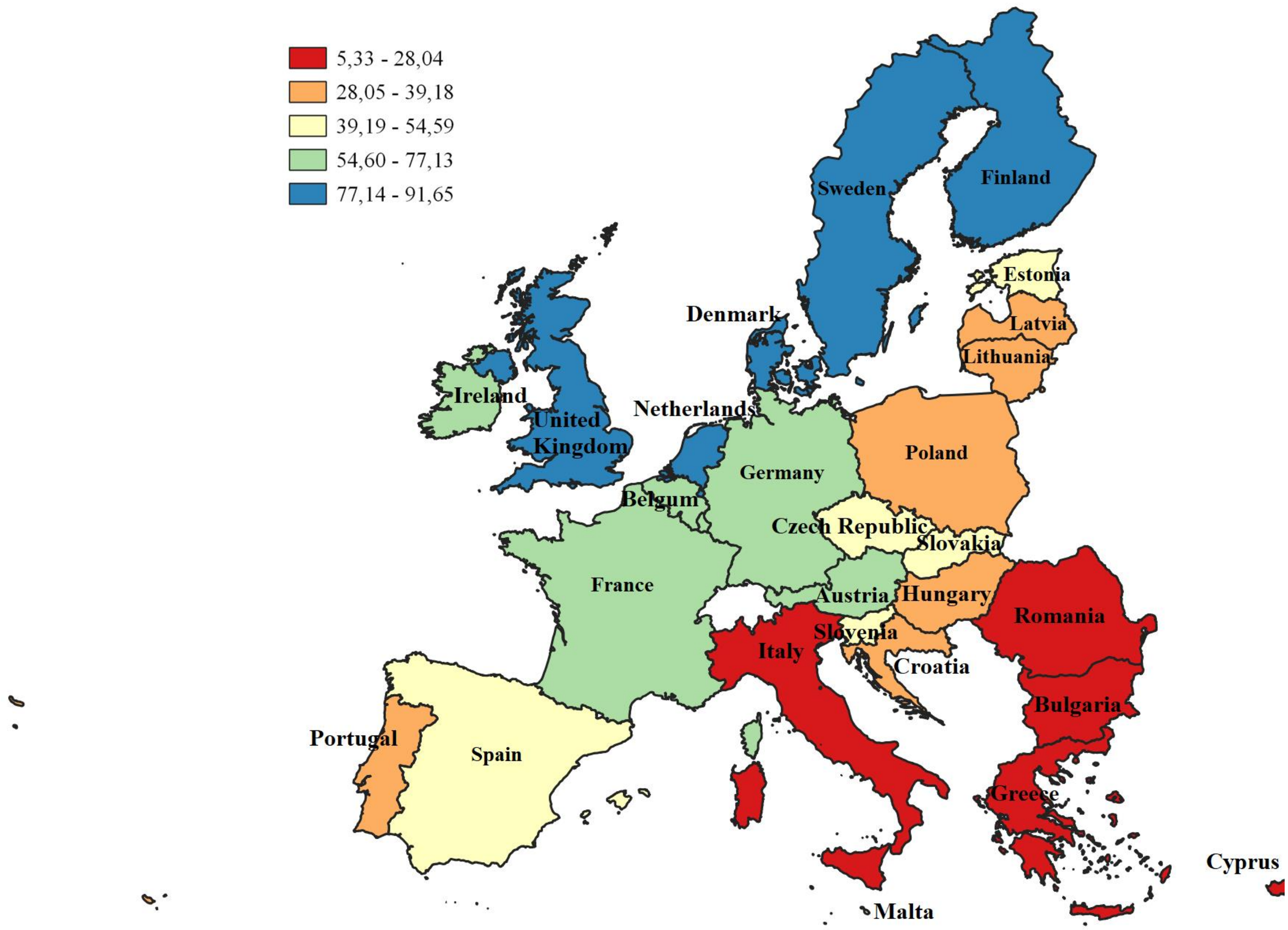


**Figure 1.** Classification map of the EU countries by values of the integral indicator of the Internet technology use in quintile groups in 2012

*Source:* Developed by the authors in QGis 3.18 based on the values of the integral indicator constructed by the authors

According to the values of the integral indicator of the Internet technology use in 2012, quintile group 1 includes Bulgaria, Greece, Italy, Cyprus, and Romania; quintile group 2 includes Bulgaria, Greece, Italy, Cyprus, Romania, Hungary, Croatia, Latvia, Lithuania, Poland, and Portugal; quintile group 3 includes the Czech Republic, Estonia, Spain, Malta, Slovenia, and Slovakia; quintile group 4 includes Belgium, Germany, Ireland, France, Luxembourg, Austria; and quintile group 5 includes Denmark, the Netherlands, Finland, Sweden, and the United Kingdom.

**Figure 2.** Classification map of the EU countries by values of the integral indicator of the Internet technology use in quintile groups in 2019/2020

*Source:* Developed by the authors in QGis 3.18 based on the values of the integral indicator constructed by the authors

In 2019/2020, quintile group 1 includes Bulgaria, Greece, Portugal, Italy, and Romania. Quintile group 2 includes Hungary, Poland, Croatia, Latvia, Lithuania, and Slovakia. Quintile group 3 includes the Czech Republic, Malta, Austria, Cyprus, Slovenia, and France. Quintile group 4 includes Luxembourg, Germany, Estonia, Ireland, Luxembourg, Austria, Spain, and Belgium, and quintile group 5 includes Denmark, the Netherlands, Sweden, Finland, and the United Kingdom.

Comparing the values of 2012 and 2019/2020, a part of the EU countries decreased or increased their quintile group position, but for some EU countries, the quintile group position did not change. Estonia, Spain, and Cyprus increased their position in the quintile group compared to 2012, while Austria, France, Slovakia, and Portugal decreased it. The position of the quintile groups remained unchanged in Sweden, Denmark, the Netherlands, Great Britain, Finland, Luxembourg, Belgium, Germany, Ireland, Malta, the Czech Republic, Slovenia, Hungary, Croatia, Latvia, Lithuania, and Poland.

According to the abovementioned, values of the indicator of Internet technology use are divided into four problem classes. (see Table 3):

**Table 3.** Problem matrix

| | | Position in relation to other regions (by quintile groups) | |
|---|---|---|---|
| | | Deteriorating or remained unchanged | Improving |
| Position of the region in relation to past results (dynamics) | Deteriorating | *Problem group 1*: Sweden, Luxemburg, France, Slovakia, Slovenia, Portugal, Bulgaria | *Problem group 2*: - |
| | Improving | *Problem group 3*: Denmark, Netherlands, Finland, United Kingdom, Belgium, Germany, Ireland, Malta, Czech Republic, Hungary, Croatia, Latvia, Lithuania, Poland, Greece, Italy, Romania, Austria | *Problem group 4:* Estonia, Spain, Cyprus |

*Source:* developed by the authors based on Lavrinenko 2010, 2015

According to the problem matrix (see Table 3), problem class 1 includes such EU countries as Sweden, Luxembourg, France, Slovakia, Slovenia, Portugal, and Bulgaria. For countries in problem class 1, the position in relation to other EU countries and the position in terms of past indicators deteriorated. Having analysed indicators of each problem class 1 EU country included in the integral indicator, it can be concluded that in **Sweden**, the indicators deteriorating the integral indicator, i.e. the lowest of the 12 indicators, are the proportion of individuals who have ordered/purchased goods or services via the Internet for private use in the last three months, the proportion of individuals who use the Internet to participate in social networks, the proportion of individuals who use the Internet to sell goods or services, and the proportion of companies that use Customer Relation Management software.

In **Luxembour**g, the indicators that lower the integral indicator are the companies that receive orders online (at least 1%) and make e-commerce sales at least 1% of their turnover, the proportion of companies that use Customer Relation Management software, the proportion of individuals who use the Internet to sell goods or services, and the proportion of individuals who have used the Internet to communicate with public authorities.
In **France**, the indicators that lower the integral indicator of internet technology use are the percentage of households with broadband internet access, the proportion of individuals who use the Internet to participate in social networks, the proportion of companies that use Customer Relation Management software, and the companies that receive orders online (at least 1%) and make e-commerce sales at least 1% of their turnover.

The lowest indicators of the **Slovak** integral indicator that negatively affect the overall integral indicator are the companies that receive orders online (at least 1%) and make e-commerce sales at least 1% of their turnover, the percentage of households with Internet access at home, and the percentage of households with broadband internet access.

In **Slovenia,** the lowest indicators included in the integral indicator are the proportion of individuals who have ordered/purchased goods or services via the Internet for private use in the last three months, the proportion of individuals who use the Internet to participate in social networks, the proportion of companies that use Customer Relation Management software, companies that have received orders online (at least 1%), and the companies that receive orders online (at least 1%) and make e-commerce sales at least 1% of their turnover.

In **Portugal,** the lowest indicators are: the percentage of households with broadband Internet access, the proportion of individuals who have ordered/purchased goods or services via the Internet for private use in the last three months, the proportion of individuals who have ever used the Internet, and the proportion of individuals who use the Internet to sell goods or services.

**Bulgaria**'s lowest indicators are the percentage of households with the access to the Internet at home, the percentage of households with broadband Internet access, the proportion of individuals who have ordered/purchased goods or services via the Internet for private use in the last three months, the proportion of individuals who use the Internet to order goods or services, the last online purchase within 12 months, the percentage of individuals who use the Internet for goods or to order services, the last purchase online, and the companies that receive orders online (at least 1%) and make e-commerce sales at least 1% of their turnover.

It can be concluded that in 5 out of 7 EU countries - Slovenia, Slovakia, Luxembourg, France, and Bulgaria, which belong to problem class 1, the lowest indicator is the share of companies that receive orders online (at least 1%) and whose e-commerce sales comprise at least 1% of their turnover. Similarly, in Sweden, Luxembourg, Slovenia, and France, the proportion of companies using Customer Relation Management software to analyze customer information for marketing purposes is low compared to other 12 indicators.

Analyzing the Barro regression and coefficients of variation and amplitude, β-convergence and σ-convergence are established.

**Table 4.** Barro regression

| | Constant | β | Value |
|---|---|---|---|
| $y=a+\beta x$ ,<br>where y= ln (index2019_2020/index2012),<br>x= ln (index2012) | 1,316 | -0,307 | 0,000 |

*Source:* the authors' calculations based on the values of the integral indicator in the SPSS programme

*Note:"index2019/2020" – values of the integral indicator in 2019/2020,*
*"index2012" – values of the integral indicator in 2012.*

Thus, from the data in the Table 4, we obtain the equation ln (index2019_2020 / index2000) = 1,316-0,307*ln (index2012) and, since β = -0.307 <0, countries with an initially low value of the integral indicator increase the value of this indicator much faster than countries with initially higher growth rates of the indicator.

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**Table 5.** Amplitude and variation coefficients of the integral indicator of the Internet technology use

| Variation coefficients | 2012 | 2019/2020 |
|---|---|---|
| Amplitude coefficient, $(K_R)$ | 1.78 | 1.53 |
| Year 2012 = 100% | 100% | 86% |
| Variation coefficient, $(V_\sigma)$ | 0.5 | 0.41 |
| Year 2012 = 100% | 100% | 82% |

*Source:* the authors' calculations based on the values of the integral indicator in the SPSS programme

Analyzing the dynamics of these coefficients in relation to the key parameters, it is possible to provide a qualitative and quantitative description of the existing disparities in the growth in the values of the integral indicator of Internet technology use in the EU.

From 2012 to 2020, the variation coefficient decreased by 18% and the amplitude coefficient decreased by 14% (Table 5). Therefore, there is a decrease in disparities in the use of Internet technology in the EU countries during the period under study.

## Conclusions

The authors of the research propose a methodology for constructing an integral indicator of technology use, as well as review the levels of technology use in the EU countries. Based on the constructed digital indicator and its distribution by quintile groups, the authors conclude that there are disparities in the level of Internet technology use in the EU countries in 2012 and 2020. There is a huge gap in the values of the integral indicator of Internet technology use between Romania with the worst indicator value of 5.33 units and Denmark with the best indicator value of 91.65 units: the indicator values in Romania are 17 times worse than in Denmark. In 2020, the worst indicator value in Bulgaria (9.15 units) is already 10 times lower than in Denmark (91.91 units). Thus, disparities in this indicator decrease during the period under study, as clearly evidenced by the decrease in the coefficients of amplitude and variation (sigma-convergence), as well as the negative beta-coefficient in the Barro regression (beta-convergence). The role of convergence of the innovation and technological structure according to the indicators of infrastructure and the use of Internet technology, which is the result of the interpenetration and combination of various technological innovations, cannot be underestimated. Therefore, a technological paradigm is being formed, in which new technologies and the technical unity of the EU countries based on the digitalization of technological processes and available global communications used, has become a structure-forming resource in the economy. The convergence of technological structure is represented as the merger of individual innovations into a system in which the combination of developing technologies creates new industries. In the context of ongoing digitalization, the driving force is a profound modification of economic relations under the influence of the global spread of convergent innovations, such as the emergence of a network form of investment and production management, the gradual loss of the emission-central role of the state as cryptocurrencies develop and new forms of entrepreneurial self-organization (blockchain) emerge.

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