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AKADÉMIAI KIADÓ

Can Central and Eastern European countries lead on digitalization? Using Digi-Index to analyse technological progress and potential

ANDREEA-DIANA VODĂ[1*], GABRIEL BRĂTUCU[1**], ANDRA IOANA MARIA TUDOR[1], RAREȘ BRĂTUCU[2], IOANA BIANCA CHIȚU[1], LAVINIA DOVLEAC[1], ALINA SIMONA TECĂU[1] and ADRIAN TRIFAN[3]

[1] Department of Marketing, Tourism-Services and International Affairs, Transylvania University of Brasov, Eroilor 29, Brasov, Romania

[2] Department of Marketing, Bucharest University of Economic Studies, Romania

[3] Department of Finance, Accounting and Economic Theory, Transylvania University of Brasov, Romania

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ABSTRACT

The degree of digitalization and potential of growth in this sector are the new criteria that split the countries into various groups. The aim of this research is to find an easier and faster method of assessing the level of digitalization for countries, over different periods, having a sample 10 countries from Central and Eastern Europe. The research compares and groups these countries, determining the impact of four additional variables on their digitalization level. There were combined multiple analyses including comparative, cluster and panel analysis. As a result, we defined a new standardized indicator, named Digi-Index, which can be adapted for various time ranges, countries or study groups. Academic researchers or business practitioners can use the Digi-Index, the clusters and their characteristics to build development plans for the digital sector, based on each country's conditions, potential and influence factors.

KEYWORDS

Digi-Index, digitalization, digital performance, technological progress, digital growth, CEE countries

* Corresponding author. E-mail: andreea.suciu@unitbv.ro
** Corresponding author. E-mail: gabriel.bratucu@unitbv.ro

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1. INTRODUCTION

The aim of this research is to find an easy and fast method of assessing the level of digitalization for various countries, over different periods, having as a sample the group of Digital Challengers (Novak et al. 2018) from Central and Eastern Europe (CEE). This category includes 10 countries (Bulgaria, Croatia, the Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia), based on their values for five variables:

1. Connectivity,
2. Human Capital,
3. Use of Internet,
4. Integration of Digital Technology and
5. Digital Public Services.

The objectives of this research are: (1) to compare the digital performance of the CEE countries in order to identify their weak points; (2) to group these countries by their performance assessed using Digi-Index; and (3) to determine the correlations between the Digi-Index and other variables related to the digitalization process and digital behaviour.

The research method consists of a three-step analysis: 1) comparative analysis, in order to summarize and compare differences across the analysed Digital Challenger countries; 2) cluster analysis, to define homogenous groups (clusters) from these Challenger countries and analyse each of them according to its main grouping characteristics; and 3) panel data regression analysis to determine the correlation between the Digi-Index and certain factors. We chose this method considering the available cross-sectional – both territorial and chronological – datasets for each cluster, using sets of data from the latest 10-year period, collected from two sources (a McKinsey report and the Eurostat database). A data coding process was necessary to create a new variable, named as Digi-Index, which calculates the degree of digitalization for a country.

1. The comparative analysis for the Digital Challengers was performed considering some significant variables related to business digitalization: internet access, company website, employees using a computer with internet access while working, online sales and online purchasing. The conclusion of this analysis is that it is difficult to measure the overall performance of these countries, considering the fact that they succeed in some parts, with high scores and fail in others, with low scores.
2. The cluster analysis, applied to the Digital Challengers, generated four clusters of countries based on their average growth rate and the level of digitalization (measured using Digi-Index).
3. The correlation between the Digi-Index and four additional variables includes: individual online purchase behaviour, education attainment level, R&D expenditures in the high-tech sector and high-tech exports. For all the clusters, online purchase and education have a positive relationship with the Digi-Index, meaning that an increase in either of these variables

will result in an increase of the digitalization level. The R&D and high-tech exports have both positive and negative relationships, so no pattern among the clusters can be determined.

The paper is structured in five sections. The first Section creates a theoretical frame of the study, highlighting the importance of the digitalization process in the context of the digital economy, for each company and for the business environment, and their sustainable development. The second Section presents the research method, the data collection method and the variables. The third Section describes the results for all three types of analyses, while the last Section is reserved for the conclusions.

2. LITERATURE REVIEW

Digitalization, namely the convergence between the real and the virtual world, is the most important factor for change, both for society and the business environment, and a decisive factor for progress (Kagermann 2015; Trașcă et al. 2019) and sustainable development (Kotler et al. 2017). The growth rate of digitalization affects society as a whole, both individuals and companies (Kessler – Buck 2017); and digital transformation, the use of new technologies (cloud, mobile devices, big data and social network) and the growth of automation, all bring new business opportunities (Salminen et al. 2017). Studies conducted in 2018 state that 89% of the world's companies planned to adopt *digital-first business strategy* but only 44% have actually adopted it until 2018 (IDG 2018).

The process of defining the digital economy involves three important issues: *the core of the digital economy* which is the digital sector that produces the basic digital products, *the digital economy* which encompasses the digital sector and emerging digital and platform services, and *the digital economy* which involves the digitalization of all economic sectors. Thus, it becomes a priority for future research to focus on identifying barriers and the impact of the digital economy in the developing countries (Bukht – Heeks 2017), on identifying key changes that will occur inside companies, changes due to the digitalization process in the transition to the digital economy (Khitskov et al. 2017), and also, how companies can influence the digitalization process in the effort to turn business models into the sustainable ones (Parida et al. 2019).

The specialists support the need of implementing digital education to improve the quality of education in general, as well as the qualification of teachers for the digital transformation of the society in order to improve digital skills, thus contributing on increasing a country's competitiveness (Khitskov et al. 2017; Novak et al. 2018).

The interest of the academic world in the impact of digitization is demonstrated by existing studies that explore how the digitalization process affects the economies of the countries, business models (Italy, Spain and Germany), different sectors of the economy (automotive, B2B, publishing and retailing) and other social aspects.

Even if there is a high failure rate for digital companies, and there are few studies examining the cause of these failures, digitalization-based economic development is considered the key to economic growth (Ammirato et al. 2019). At the same time, the literature shows that there is only few research done on the opportunities, challenges and success factors of digital entrepreneurship (Kraus et al. 2018; Rachinger et al. 2019; Vial 2019), supporting the need for holistic approaches to the implications of digitalization on entrepreneurship (Nambisan et al. 2019). In this respect, six research areas related to digital entrepreneurship were identified: "digital

business models; digital entrepreneurship process; platform strategies; digital ecosystem; entrepreneurship education; and social digital entrepreneurship" (Kraus et al. 2018).

Digitalization leads to the reformulation of business models and the emergence of new management approaches (Heavin – Power 2018), with consequences on employment (Loebbecke – Picot 2015), to the rethinking of entrepreneurial opportunities and practices, thus offering new ways of companies' internationalization (Joensuu-Salo et al. 2018). Given the fact that digital technology is increasingly present in the companies' activity, the question of the efficient management of digital innovation is posed, as firms need dynamic tools for this purpose (Nylén –Holmström 2015).

The digitalization implies a rapid adaptation of the business models to the created ecosystems, and the specialists suggest new dimensions for them based on:

- *Structure design* – network formed by partners (including clients and other parties that can add value);
- *Accomplishment of activities* – the creation of value through the logical organization of digital technologies; and
- *Governance* – establishing the reasons and conditions for collaboration for those involved (Turber et al. 2015).

In everyday life, we are witnessing the "digitalization of the individual" (Matt et al. 2019) meaning that people use all kinds of connected devices, share information and build networks. Thus, in the economic environment, companies have to find a place in deeply connected ecosystems and this can be achieved by adapting strategies and creating new business models that increase their performance (Paulus-Rohmer et al. 2016; Bouwman et al. 2018; Rachinger et al. 2019; Aulkemeier et al. 2019). In the context of the application of new technologies such as, the Internet of Things, Big Data and Cloud Computing, the business model practiced by companies is an important tool for gaining the competitive advantage (Chen et al. 2018; Bouwman et al. 2018). At the same time, new ways of collaborating between companies, new products and services, and also new forms of customer relationship are being developed (Krämer et al. 2017; Hendriyani – Auliana 2018; Rachinger et al. 2019).

In digital innovation, resources are used as "building-blocks". They can be a part of multiple value paths through being combined and recombined in different ways (Henfridsson et al. 2018). However, small- and medium-sized enterprises (SMEs) have limited resources to implement new strategies in the digitalization process. A study conducted on 321 SMEs revealed that the allocation of more resources for digitalization, for the active use of Social Media, Big Data and Information Technology in the business models, has a positive impact on their overall performance (Bouwman et al. 2019).

The implementation of new digital technologies helps companies overcome the traditional barriers related to services, helping accelerate the offer and separate it from the human factor, thus increasing the efficiency of these companies (Laudien – Pesch 2019).

In a constantly changing economy, firms must also adapt through internal changes that create value for both collaborators and customers, and this involves understanding the functioning mechanism of the digitalization process, digitized communications and consumer digitization (Crittenden et al. 2019). Adapting to the challenges of the digital economy also involves adapting marketing practices, thus the concept of Marketing 4.0 has emerged, which combines online and offline interaction between companies and consumers (Kotler et al. 2017).

The characteristic of the digital economy is the fact that it communicates with the "communities" of consumers (naturally formed by them) and the classic concept of marketing mix has evolved to involve more consumers, becoming a connected marketing mix of the 4Cs: co-creation (new product development strategy), currency (dynamic pricing), communal activation (instantly access to product) and conversation with customers (Kotler et al. 2017).

At the institutional level, due to the effects produced by digital innovation, the specialists identified three new types of institutional structures – "digital organizational forms, digital institutional infrastructures, and digital institutional building blocks", raising the need of studying how they can gain social legitimacy and interact with the existing structures (Hinings et al. 2018).

3. RESEARCH METHOD

The main objective of the research was to test the hypothesis which assumes that the explanatory variables significantly influence the independent variable and determine their degree of influence. Digital single market – promoting e-commerce for individuals, educational attainment level, high-tech exports and enterprise R&D expenditure in high-tech sectors – influence the value of Digi-Index, which determines the degree of a country's digitalization.

Based on a McKinsey report (Novak et al. 2018) several countries were selected. According to their degree and potential of digitalization, the report split the European countries in various groups. Five variables were taken into consideration: Connectivity, Human Capital, Use of Internet, Integration of Digital Technology and Digital Public Services. As a result, the countries were grouped in three major sets: *EU BIG 5* (France, Germany, Italy, Spain and United Kingdom), *Digital Frontrunners* (Belgium, Denmark, Estonia, Finland, Ireland, Luxembourg, the Netherlands, Norway and Sweden) and *Digital Challengers* (Bulgaria, Croatia, the Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia). Our research focuses on the analysis of the Digital Challengers countries and aims to provide a better understanding and classification of the countries among this group, a group that proves a strong potential for growth in the "digital economy".

As a first step, based on a time series analysis, we determined the average overall growth for each country in the digitalization context. Based on the five components originally analysed, a new variable – the so-called "Digi-Index" – was determined and used to cluster the Digital Challengers countries. In this way, four clusters were generated and the impact of additional four variables was evaluated.[1]

3.1. Data gathering

The data gathering was a two-step process. As source for initial data selection, we used McKinsey's report (Novak et al. 2018), identifying the 10 countries, which have a significantly low level of digitalization but a high potential of growth in this area, namely the Digital Challengers and additional variables were determined. The second datasets were collected from

[1]The analysis was carried out in SPSS Statistics, a software package used for statistical analysis and eViews 11 statistic software used especially for econometric analysis.

Eurostat Statistical System, which is the European Commission platform that collects data and provides statistics across the EU members. As input for the extraction of the selected countries data, we used the following path on Eurostat: Science, technology, digital society – Digital economy and society – ICT usage in enterprise. Five variables were selected to be further analysed and based on data availability, they were collected from the following time-ranges: 2010–2019 and 2010–2020. It should be specified that due to the recentness of the topic, a limited data before year 2010 was found, and this explains the short-time range analysis. The following five datasets were chosen: Internet access, Websites and functionalities, Use of computers and the internet by employees, E-commerce sale and E-commerce purchases. Data selected was expressed as a percentage of either companies or individuals (employees) from each country.

For the second and third parts of the research, additional data was collected to be used as explicative variables. The following main datasets were selected: Digital single market – promoting e-commerce for individuals, Educational attainment level, High-tech exports and Business enterprise R&D expenditure in high-tech sectors. At the end, 884 record sets were collected, for 10 countries, from nine databases on a 10-year period each, being defined as five components and four explicative variables. The missing values were either ignored or replaced by mean values, depending on the type of analysis.

3.2. Data coding and standardization

Due to the fact that data gathered is expressed as percentages from different bases, a data coding process was applied, to be able to conduct the analysis. Using the five component variables and based on their standardized values, a variable, generic called "Digi-Index", was obtained for each country. The method used was to average all variables for the entire time range at a pace calculated based on t/t-1, the "Digi-Index" formula being presented below:

$$Digindex = \frac{\sum \overline{Z_{x_i}}}{n}$$

Based on the standardized values, it/t-1 was calculated and the index dynamic was generated. This was used to obtain the Average growth index. A step-by-step calculation is described in Table 1.

Table 1. Data coding and standardization steps and formulas

Step	Variable	Formula
1	Standardized values	$Z_{ij} = \frac{x_i - x_{mean}}{S_{ij}}$
2	Mean	$x_{mean} = \frac{\sum x}{N}$
3	Digi-Index	$Digindex = \frac{\sum \overline{Z_{x_i}}}{n}$
4	Index of dynamic average	$\bar{i} = \sqrt[n-1]{\prod_{t=2}^{n} i_{\frac{t}{t-1}}} = \sqrt[n-1]{i_{\frac{n}{1}}}$
5	Average growth index	$\overline{r_{\%}} = \overline{i_{\%}} - 100$

The Digi-Index and Average growth index were used further in this research to determine clusters and test hypothesis using various analyses.

As part of our research, the correlation coefficient was calculated in order to determine the strength and direction of the linear relationship between Digi-Index and the aspects related to the individual online purchase behaviour, education attainment level, R&D expenditures in the high-tech sector and high-tech exports, considered to be the explicative variables in this model. This coefficient was calculated with the formula below:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x^2)][n\sum y^2 - (\sum y^2)]}}$$

The *r* value is located within the range [−1; 1], the – and + signs indicating the direction of the linear correlation, whether it is negative (−)or positive (+) respectively (Petcu 2009).

To be able to better determine the influence of the individual online purchase behaviour, the education attainment level, as well as of the R&D expenditures, and the expenditures in the high-tech sector, a panel regression analysis for each cluster was conducted. The following model was used, where y represents the dependent variable, x the independent one, a_0 the unknown intercept, a_1 the coefficient of x_{it} and u_{it} the error term:

$$y_{it} = a_0 + a_1 x_{it} + u_{it}$$

The panel regression was run for the three clusters (i), for either 9 or 10 years (t) depending on the data availability. The Panel Least-Squares technique was used to prove the potential relationship between the Digi-Index, as the dependent variable, and the four above-mentioned variables as the independent variables.

4. RESULTS

4.1. Comparative analysis

The 10 countries of CEE listed in the Digital Challengers group have similar trends when taking into consideration the digitalization of businesses. Therefore, a series of significant variables related to business digitalization have been selected in order to compare either the evolution, or the involution of all these countries. The first variable is the internet access. The percentage of companies that have internet access, presented in Figure 1, has been steadily developing for all countries, however, it is still an issue for some of them. For example, Croatia and Hungary have less than 95% of companies that currently have internet access. What is interesting is that besides the annual growth of Hungary (6.81% increase from 2014 to 2020), the percentages for Croatia slowly deteriorating, with a decrease of 2.08% from 2014 to 2020. Romania is still at the bottom of the ranking, being the only country in the group with more than 10% of its companies without internet access (almost 20%, to be precise). On the other hand, countries such as Lithuania (100% from 2014 to 2020), Latvia (100% from 2018 to 2020), Slovenia (99% from 2015 to 2020) and Poland (99% in 2020) dominate the ranking, being comparable with the Western and Nordic countries within Europe. To be noted that no data was found for the year of 2019 (Eurostat 2020a).

Another important variable for today's digitalized world could definitely be the percentage of companies that have a website, presented in Figure 2, since this criterion is quite

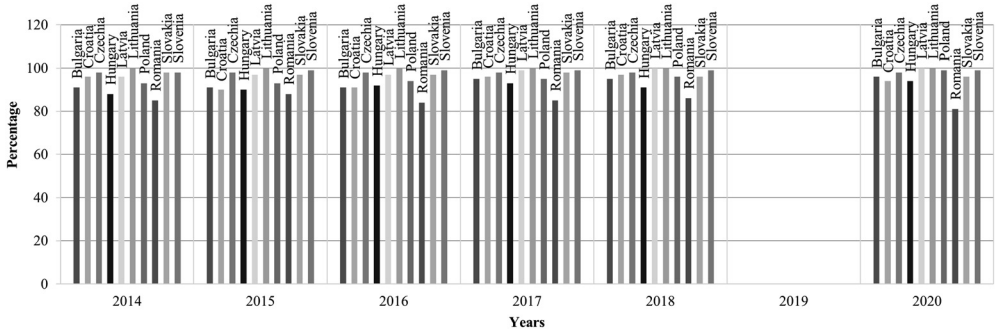

Fig. 1. Percentage of companies with internet access in Central and Eastern Europe

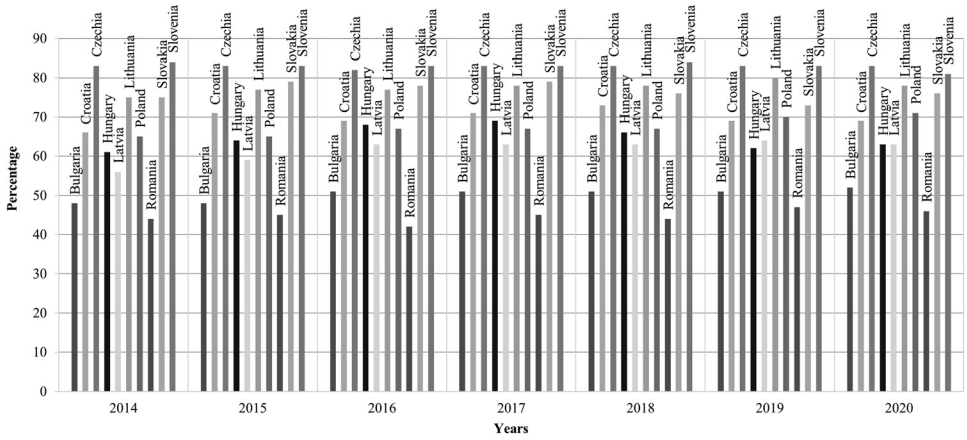

Fig. 2. Percentage of companies with a website in Central and Eastern Europe

important not only from the perspective of consumers, but for the stakeholders as well. Once again, the data shows that Romania ranks bottom in this criterion, with less than 50% of their companies owning a website and having a small growth of 4.5% from 2014. Bulgaria ranks second with just shy over 50% of their companies owning a website (however, their growth is much more significant from 2014, being around 8.3%). Following these two countries are Hungary and Latvia, both having around 63% in this criteria. On the other way around, the top countries in this ranking are Czech Republic and Slovenia, both having more than 80% of companies owning websites. At the same time, even though Latvia is not ranked high in this particular criterion, it had the highest growth from 2014, namely 12.5% (Eurostat 2020b).

The third variable taken into consideration is different, as it is used to measure the percentage of employees using a computer with internet access while working (percentage of the total employment in each country), is presented in Figure 3. As some countries have similar growing trends with others, all countries will be categorised into specific groups: 0–10% increase: Latvia (7.3%); 11–20% increase: Slovenia (14.9%), Croatia (19.0%) and Romania (20.7%); 21–30% increase: Slovakia (26.3%), Hungary (29.6%) and Czech Republic (28.9%); 31% and more: Poland (38.9%), Bulgaria (41.7%) and Lithuania (44.7%). Even though Romania has an impressive growth, it is still not ranked high, as it takes the second to last place after Bulgaria (both having around 35% of the employees using computers with internet access). However, Bulgaria has one of the highest growth rates, meaning that it might step up in the ranking in the following years. Lithuania and Slovenia are once again at the top of the chart, both having around 55% of their employees using computers with internet access. Moreover, Lithuania has the highest growth from 2014, meaning that it is the top performer country in this criterion (Eurostat 2020c).

The next variable is more specific, as it refers to the percentage of companies that are selling online, data presented in Figure 4. Lower percentages are expected to be seen compared to the basic digital variables such as the ones analysed before. Therefore, as each country has different consumer trends, there are few similarities between them. It is interesting to see that a significant number of countries has fluctuating trends. For example, Czech Republic, which has maintained its top position in the 6-year period, has a modest growth in percentage, having an increase of 10.7% in the period. However, its growth fluctuates significantly, having two decreases in the 7-year period. Romania and Latvia have had the highest rises in terms of percentages, Romania having an impressive growth of 137.5% (from 8% of companies in 2014 to 19% in 2020) and Latvia having a growth of 77.8% (from 9 to 16%). It is interesting to see that both countries had similar situations in 2014 and relatively similar growing trends in the period. Other countries

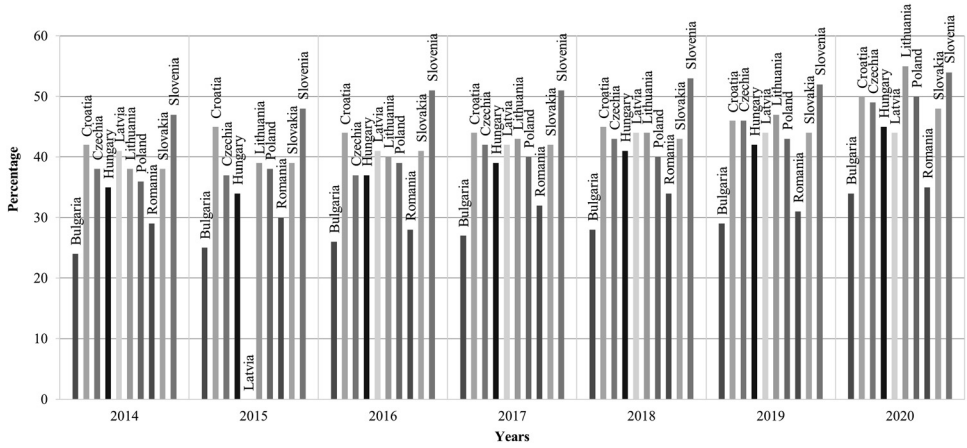

Fig. 3. Percentage of total employment of employees using a computer with internet access in Central and Eastern Europe

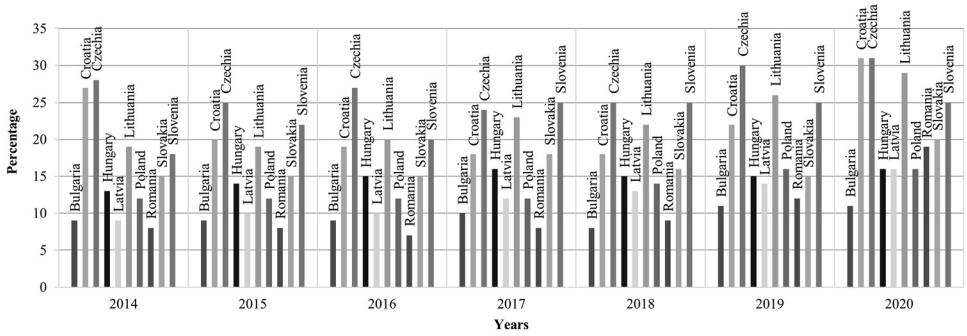

Fig. 4. Percentage of companies selling online in Central and Eastern Europe

that have impressive growths are Lithuania (52.6%), Slovenia (38.9%), Poland and Slovakia (both having 33.3% increases). Bulgaria is once again at the bottom of the ranking, having fluctuating values (around 9–11% of its companies selling online). On the other way around, Croatia and Czech Republic occupy the first place, both having around 31% of their companies selling online (Eurostat 2020d).

The final figure continues to be more specific when considering the level of digitalization of companies in a country. Being an important criterion in the digital area, especially in the business world, the possibility to purchase online definitely helps businesses grow, and thus, help countries be more competitive at the global level. Figure 5 shows the percentage of companies that purchase online. However, once again, no data was found for the last two years, meaning that the analysis was done over the 2014–2018 period. Moreover, there are some missing values for Croatia, Romania and Slovenia. Compared to the preceding Figure 4, there are some similarities, as the variables are similar. Czech Republic is at the top once again, dominating the ranking for all five years, having a continuous growing trend of 12.9% (from 54% in 2014 to 61% in 2018). However, Czech Republic has a small growing trend compared to other countries in

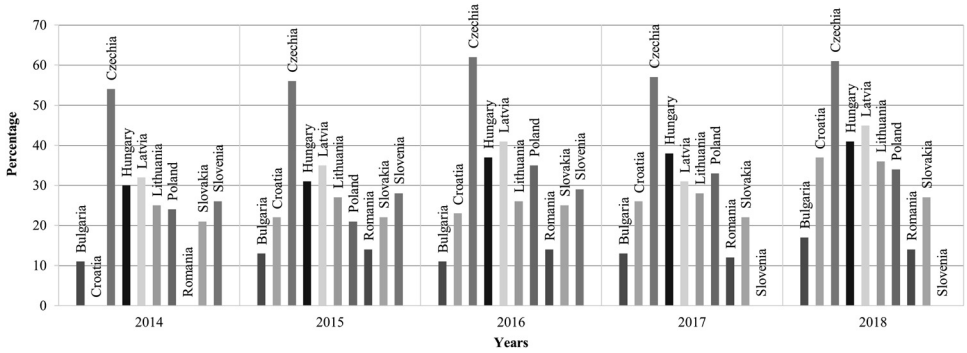

Fig. 5. Percentage of companies purchasing online in Central and Eastern Europe

the ranking. For example, Croatia has an impressive growth of 68.2% (from 22% in 2015 to 37% in 2018), being followed by Bulgaria, which had an impressive growth of 54.5% compared to its positions in other variables (from 11% in 2014 to 17% in 2018), Poland with 41.7% (from 24 to 34%) and Latvia with 40.6% (from 32 to 45%). Romania is the only country with no growth in this particular variable, being ranked last at the same time. Even though the possibility to purchase online could not be seen as that popular among companies while looking at the percentages for the first time, these growths show that they are definitely taken into consideration and that these practices are becoming more and more popular (Eurostat 2020e).

As to what conclusions could be drawn from all five variables, it is difficult to measure the overall performance, as some countries which are at the bottom of the ranking have impressive overall growths for the five years period, and some countries which are constantly ranked high have smaller increases. Therefore, Table 2 illustrates two key elements: the average growth for each country, for all five variables and the number of times each country ranked in the top three for each of the five variables.

It is clear that countries such as Czech Republic and Slovenia, which had impressive results in all variables, have smaller growths, since their values are already high compared to other countries. However, since countries such as Romania, Latvia, Bulgaria and Poland, which are not as developed in the digital world as their neighbours and some of them did not score well in the rankings (such as Romania and Bulgaria), any slight increase in the percentage of a variable for them would be more significant than for other more developed countries. For example, in Figure 5 (companies purchasing online), Bulgaria (from 11 to 17%) and Slovakia (from 21 to 27%) had the same growth in percentage points, but the overall percentage increase is significantly different, as Bulgaria had a 54.5% growth and Slovakia had only a 28.5% increase. Therefore, all countries have impressive results, as the developed countries (in the digital world) maintain their growth and their positions at the same time, and the undeveloped countries,

Table 2. Average overall growth and rankings of Digital Challengers countries (based on Digi-Index values)

Countries	Average overall growth, %	Top 3 countries in 2020, all 5 variables
Romania	31.60	Not in top 3
Lithuania	29.07	4 times in top 3
Latvia	28.47	2 times in top 3
Bulgaria	26.45	Not in top 3
Poland	25.91	2 times in top 3
Croatia	20.90	2 times in top 3
Hungary	19.68	1 time in top 3
Slovakia	17.50	Not in top 3
Slovenia	12.55	3 times in top 3
Czech Republic	10.52	3 times in top 3

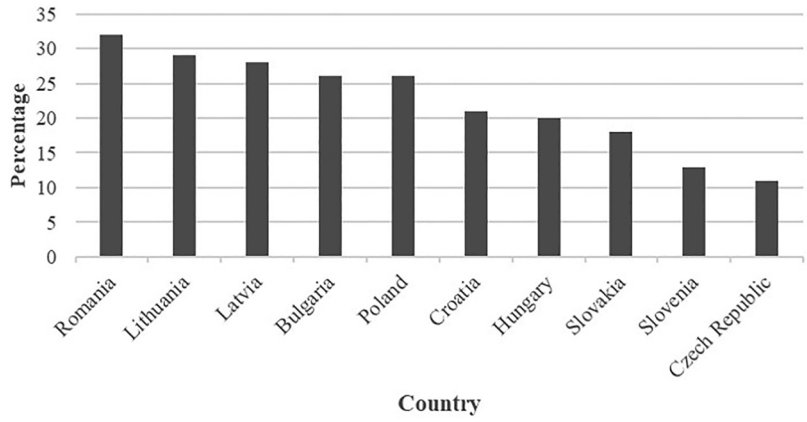

Fig. 6. Digital challengers countries average overall growth

digitally speaking, are seeing massive improvements and are getting closer to the top countries, as shown in Figure 6.

It can be stated that the Baltic countries (Lithuania and Latvia) have had the best progress so far, as Lithuania has not only one of the biggest growths for all variables (29.1%), but also appeared four times in the top 3 for each of the five criterions, being followed by Latvia, which also has an impressive overall growth (28.5%) and also appeared two times in the top 3. To be noted is that Romania and Bulgaria, which scored low in most of the variables, will have a certain level of competitiveness in the foreseeable future, as their growths are outstanding.

4.2. Cluster analysis

For the cluster analysis, two variables were taken into consideration: the Digi-Index and the Average Growth Rate, were obtained as previously described (Table 3). As a result, four clusters were generated as can be seen in Figure 7, grouping all 10 countries based on their current degree of digitalization and their potential to grow in this area.

Table 3. Digital challengers countries grouped by clusters

Cluster #	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Country	Lithuania	Croatia	Hungary	Bulgaria
		Slovenia		
	Latvia	Slovakia		Romania
		Poland		
		Czech Republic		

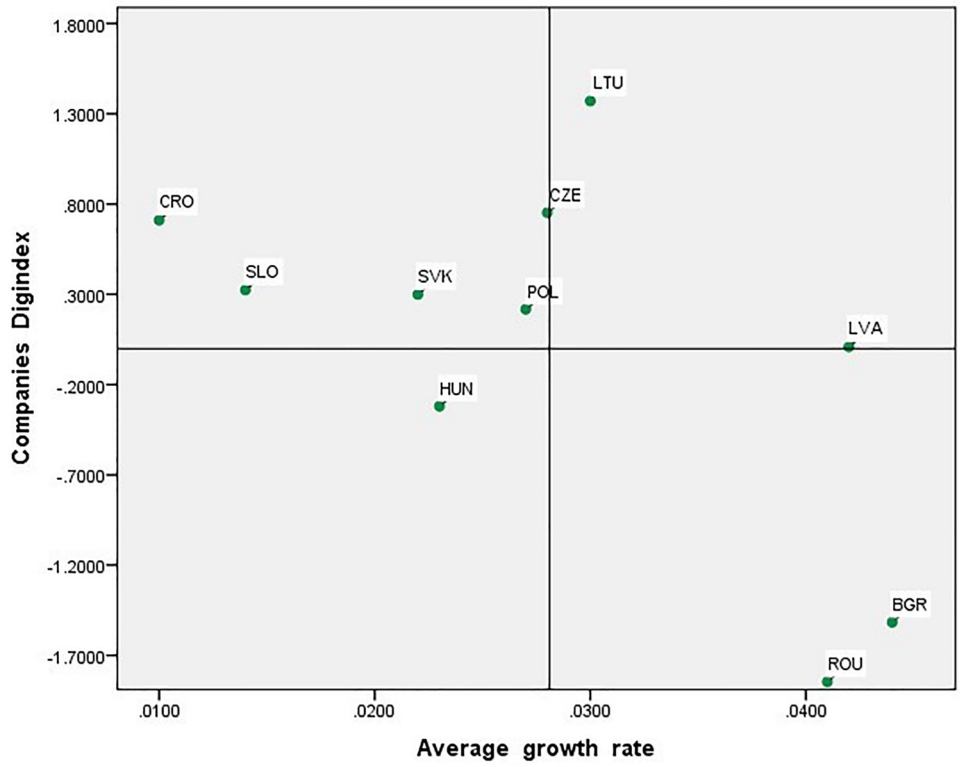

Fig. 7. Cluster analysis, position chart

The first quadrant is occupied by Lithuania and Latvia, being the countries with a good growth rate and degree of digitalization among the Digital Challengers countries. We observe that Lithuania is by far the leader of digitalization, being the country with the highest Digi-Index. With a high degree of digitalization, but a low level of growth, Croatia, Slovenia, Slovakia, Poland and Czech Republic form the largest group, although the Czech Republic is very close to becoming part of the first group, if their level of growth continues to increase. Solo in the third group, Hungary is the only country with a digitalization level and a growth rate below the mean. Bulgaria and Romania, forming the fourth cluster, show a significantly lower level of digitalization. Nevertheless, they seem to promise more, proving a high average growth rate on the digitalization area.

4.3. Correlation and panel data regression analysis

Our research analysed the correlation between the Digi-Index and four additional variables: Individual online purchase (IOP), Educational attainment level (EDUA), High-tech exports (HTE) and Business enterprise R&D expenditure in high-tech sectors (RDE).

Table 4 contains the values obtained by calculating the correlation coefficient for each cluster determined in the previous analysis, excluding Hungary, which was the only country in its

Table 4. Correlation coefficients between Digi-Index and clusters

Cluster	Cluster 1				Cluster 2				Cluster 4			
	IOP	EDUA	RDE	HTE	IOP	EDUA	RDE	HTE	IOP	EDUA	RDE	HTE
r coefficient value (Y)	0.38	0.91	−0.44	0.28	0.52	0.31	0.23	0.30	0.62	0.44	−0.20	−0.10

cluster. Although it does not provide valuable information about the predictive power of the variables, the correlation coefficient (r) is a very useful tool, identifying in this particular case the strength and direction of a linear relationship between two variables.

As can be noticed, the highest value of all can be seen on the 1st cluster – comprising Lithuania and Latvia, for the EDUA variable. With a value of 0.91, this shows a very strong linear correlation between the education attainment level and the degree of digitalization concluding that, for this group, the degree of education influences the degree of countries' digitalization. Among this cluster we can find also the lowest correlation coefficient value, −0.44 for the RDE variable. The relationship between the R&D expenditures in the high-tech sector and the Digi-Index is being weak-negative, probably because these countries already have the highest level of digitalization among the Digital Challengers group and an increase in the R&D expenditure will not lead to an increase on the digitalization level.

The correlation between the four independent variables considered for the cluster 2 case, formed by Croatia, Slovenia, Slovakia, Poland and Czech Republic and the Digi-Index is positive for all the variables. This shows a positive correlation for all of them, with the highest value (0.52) for the IOP, proving a moderate relationship between the Individual online purchase behaviour and the degree of digitalization among the countries in the 2nd cluster. Therefore, an increase in any of this variable will lead to an increase in the digitalization level.

For cluster 4, two variables have a positive relationship and the other two a negative one. Even though this cluster countries' digitalization level is the lowest one, the individual online purchase behaviour and the education attainment level positively influence their digitalization level.

In order to assess the influence of the variables IOP, EDUA, RDE, HTE on DIGI-INDEX, a panel regression analysis using the panel least squares technique was run for each of the three previously described clusters, the data are presented in Table 5.

For cluster 1, F Significance (0.000008) indicates the minimum chance that the Panel Regression Output occurred by chance. The panel regression model is a significantly good fit according to the P-value $= 0.00 < 0.05 = \alpha$. Interesting for this cluster is the fact that although the model is a significantly good fit, the education attainment level being the only independent variable significantly influencing the variation in the Digi-Index. This is even more interesting, as for the 2nd cluster this variable is the only one not significantly explaining the variation of the digital performance of the cluster. A possible explanation for this can be extended to workforce training, but this will be analysed and proved on future research. For the individual online purchase behaviour, R&D expenditures in the high-tech sector and high-tech exports, included in this model, the P-values are higher than 0.05, thus meaning that they are not significantly influencing the changes in the Digi-Index. Although not statistically significant, we consider that

Table 5. Panel regression outputs for the analysed clusters

Variable	Cluster 1		Cluster 2		Cluster 4	
	Coefficient	*P*–value	Coefficient	*P*–value	Coefficient	*P*–value
C	−1.016932	0.0013	−0.367819	0.0117	2.608331	0.1701
IOP	−0.521067	0.0694	0.444586	0.0001	2.896773	0.0822
EDUA	1.997089	0.0000	0.366499	0.1333	−0.498617	0.6359
RDE	−0.145043	0.397	0.428815	0.0007	0.440102	0.6704
HTE	0.874201	0.0582	0.492929	0.002	0.541508	0.5328
Prob (F-statistic)	0.000008		0.000000		0.12621	

the coefficients offer a good overview of the phenomenon – it should be pointed out that limited data is currently available, due to the newness of the researched topic.

Similar with the 1st cluster, the F Significance (0.0000) for the 2nd cluster states that there is a minimum chance that the panel regression output is just a chance occurrence. The panel regression model is a significantly good fit here as well, as the *P*-value = 0.00 < 0.05 = α. For the 2nd cluster, considering the *P*-values from the panel regression output, we emphasize that the model is valid, but not all the independent variables considered (individual online purchase behaviour, education attainment level, R&D expenditures, and exports in the high-tech sector) significantly influence the digital performance of the group (Digi-Index). The education attainment level appears not to significantly influence the variation in the digital performance of this cluster, as its *P*-value (0.13) is higher than 0.05. Therefore, for the countries in the 2nd cluster, the education attainment level is unlikely to be associated with the changes in the Digi-Index level. The High Technology Exports, according to this output, seems to have the highest influence in the Digi-Index variation. Therefore, a change with one unit of this value determines an increase with 49% of the Digi-Index.

The same panel regression analysis was run for the 4th cluster. For this group (including Romania and Bulgaria), the F Significance reveals that there is a 12.62% that this output was simply a chance occurrence. The *P*-value > 0.05 = α, offers the possibility to conclude for this specific cluster that the panel regression model is not a significantly good fit. For all the independent variables (individual online purchase behaviour, education attainment level, R&D expenditures in the high-tech sector and high-tech exports) in this case, the *P*-values are higher than 0.05, so the fact can be determined that no variable is significantly related to the Digi-Index in the case of the 4th cluster.

5. CONCLUSIONS

This work provides a new way of assessing the digitalization level of a country, generating the variable called Digi-Index, based on the standardization of the well-selected variables. This provides an easier way to standardize data, assess and compare digitalization among various countries, over different time periods. As the focus of the research was on the countries with lower levels of digitalization among the European states but a high degree of growth in this area, we emphasized their potential for development.

Based on our research several new ideas are emerging. Firstly, a well-determined time series analysis on the Digital Challengers countries shows either an evolution or an involution on the degree of digitalization. Beside the reports and statistics already published that analyse the degree of digitalization, we proposed five more explanatory variables proving that they can explain deeper the way technology influences a country's development. We concluded that not only the current digitalization level matters and makes a country "good" or "poor" in digitalization, but also the overall growth. As the countries in the Digital Challengers group have the lowest level of digitalization compared to other countries in Europe but a great promise on growing, we ranked them based on both criteria. With our development analysis, we managed to show which CEE countries do the best on current and future digitalization.

Secondly, the cluster analysis groups and positions all 10 countries based on their similarities and potential. In this way, we went further with the analysis and formed four additional clusters within the Digital Challengers group. We generated a new variable called Digi-Index that we considered very helpful for any other research in this area, minimizing the effort and reducing the number of steps for other given analyses. The advantage of Digi-Index is that, because of a standardized formula, it can be calculated for any time range.

At the end, the correlation between Digi-Index, which calculates the degree of digitalization for each country, and additional explicative variable was determined. Various external influence factors, determined by variables like individual online purchase behaviour, education attainment level, R&D expenditures in the high-tech sector and high-tech exports were analysed. On the first hand, we calculated the simple correlation coefficient, which shows if the variables negatively or positively influence the degree of digitalization. The analysis was run for three out of four clusters, the group containing only Hungary being excluded from the analysis due to data limitation. For all the clusters, we found out that the variables related to individuals, being online purchase and education, have a positive relationship with the Digi-Index. This means that an increase in either of these variables will result in an increase of the digitalization level. The variables related to R&D and high-tech exports both have positive and negative relationships, so no pattern among clusters can be determined.

In order to better assess the influence of the independent variables we conducted a panel analysis using the least-square method. For cluster 1 including Lithuania (the country with the highest degree of digitalization) and Latvia, the education attainment level significantly influences the Digi-Index. Nevertheless, for cluster 2 – including Croatia, Slovenia, Slovakia, Poland and Czech Republic, countries with a high degree of digitalization but low growth rate in the area – education is not significant. Here, the high-tech exports significantly influence the level of Digi-Index, as one unit change of this value determines 49% increase in the digitalization level. For cluster 4 – formed by Romania and Bulgaria, countries with a low digitalization level but high growth-rate, this model is not a good fit, as it seems that none of the independent variables is significantly related to the Digi-Index. We assume that this happened due to the lack of data available for these countries.

This research faced several limitations. Our first limitation was the amount of data available on Eurostat and World Bank databases. Because of the limited data range, we considered some of our analysis as being limited and the conclusions were partial. Our formula for Digi-Index was not tested on a wider data set, so the efficiency of the formula is not proved for a period longer than 10 years. Another limitation is related again to data availability, this time concerning the missing values for certain years, for several countries. Because of this, there were values predicted and automatically generated by SPSS statistics, questioning the accuracy of the results. As our research focused only on the Digital Challengers group, the analysis is limited to 10 countries. We suggest

future research to compare countries among other groups and conduct cluster analysis for all European countries. Because of the different data structures, and the various analyses, we were not able to limit our analysis to the use of one statistics software. The need to conduct a more complex analysis required the use of SPSS statistics and eViews 11 as additional data analysis resource.

Despite the encountered limitations, we encourage other researchers to use the Digi-Index, the four clusters and the correlations determined by us in identifying the degree of digitalization and growth, similarities, strengths, weaknesses and influence factors. This may be helpful for conducting a deeper analysis, in order to better understand the Digital Challengers countries and build concrete growth plans in the digitalization sector for them.

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