IMPACT OF DIGITALISATION AND R&D ON THE ECONOMIES OF EU MEMBER STATES

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Abstract. Digitalisation is becoming increasingly important in today's world, as digital technologies are rapidly changing the way we live and work. The COVID-19 outbreak has heavily influenced the way many businesses operate across all sectors linked to both changes in consumer behaviour, social-distancing restrictions and also the availability of resources and services (inc. public services). In many cases the processes digitalised during the pandemic are retained in a digital form also in the post-pandemic recovery thus increasing the overall level of digitalisation and contributing to the transition to Industry 4.0. That refers to additive manufacturing, artificial intelligence, big data and analytics, blockchain, cloud computing, industrial internet of things, and simulation to achieve increased efficiency, improved accuracy, reduced costs, enhanced communication and collaboration, and greater access to information and resources. These have become priorities for enhancing Europe's long-term competitiveness and will most probably be intensified in the coming years. Meanwhile, it is necessary to take into account the disparities across European Union (EU) member states in the current level of digitalisation and in the prospects of their development. This study aims to assess the digitalisation process of EU member states, its link with the research and development and innovation via factor analysis and regression. The results of the factor analysis determined the component factors and their relations; and the obtained regression model revealed the digitalization factors that can affect economic growth and contribute to GDP per capita thus being the determinants of economic growth in EU member states.

Keywords: digitalisation, Industry 4.0, R&D, GDP.

Introduction

Digitalisation refers to the process of using digital technologies to transform and automate business processes, operations, and services. It involves the integration of digital technologies into various aspects of an organization or society, such as communication, data management, production, and delivery of goods and services. The digital technologies are increasingly transforming the processes as well as the services provided by the public sector and also our everyday lives as individuals [1; 2]. The benefits of digitalisation include increased efficiency, improved accuracy, reduced costs, enhanced communication and collaboration, and greater access to information and resources [3]. This transformation is labelled Industry 4.0 [4] and it encompasses (but not limited to) additive manufacturing, artificial intelligence, big data and analytics, blockchain, cloud, industrial internet of things, and simulation [5]. For SMEs, focusing on investing in digital technologies, employee digital skills, and digital transformation strategies are factors beneficial for digital transformation and competitiveness of the enterprises [6; 7].

There are several indicators that can be used for measuring the scale of digitalisation in EU, a comprehensive way of doing so is by using the Digital Economy and Society Index (DESI), which is a composite index developed by the European Commission to measure the progress of EU member states in digital competitiveness [8]. The authors of this study have used DESI index as one of the parameters for determining the competitiveness of EU economies in a previous study [9] published in 2021. DESI index has also been used in a study that aimed to assess the correlation between digitalisation and poverty (using also the indicator "People at risk of poverty or social exclusion" (AROPE)) and it led to a conclusion that in most cases the countries with higher levels of digitalization showed a more significant reduction in poverty and social exclusion [10]. There are also several non-composite datasets that can be used to analyse digitalisation processes in EU, these will be used in this study and described under the section of Materials and methods. Digitalisation is closely linked with innovation and thus research and development (R&D) in each member state. The innovation level in each member state is also measured by a composite indicator similar to the DESI index - the European Innovation Scoreboard (EIS) [11] that provides a comparative analysis of innovation performance in EU countries. It helps countries assess the relative strengths and weaknesses of their national innovation systems and identify challenges that they need to address. If the results of the DESI index and EIS are combined, the close correlation of the digitalisation and innovation indicators can be observed – the countries leading the DESI index score in 2022 are also the ones leading the EIS score – Sweden; Finland; Denmark and the

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Netherlands. Also, the countries lagging behind in both scores are much the same – Romania, Bulgaria and Poland. In the EIS grouping Latvia is in the last group of Emerging innovators but in the DESI score it is doing better although still below the EU average [8,11]. These observations are in line with the studies of the relationship between R&D expenditures, digitalisation and level of innovation in EU member states [12; 13]. Also on an enterprise level the relation of digitalisation with the investments in R&D have been studied prior, concluding that digital transformation directly promotes the process innovation performance and product innovation performance of manufacturing enterprises. In general, the higher the technology content of an enterprise is, the more obviously the digital transformation affects its innovation performance [14].

Materials and methods

This study analyses the data from EURtat [9-20] that characterizes drivers for digitalization, the data are grouped in 5 categories – Macro; Digital infrastructure; Individuals; Enterprises and e-commerce and R&D (Research & Development) (see Table 1). The first group of indicators pertains to Main GDP aggregates per capita, which includes the GDP of each country divided by its population. The unit of measure for this group is in current prices, which is euro per capita. The data is reported for the year 2022, except for Luxembourg, which is reported for 2021.

The second group of indicators pertains to digital infrastructure. The first indicator is the level of the Internet access in households, reported as a percentage of households for the year 2022. The third group of indicators pertains to individuals, including the percentage of individuals using the Internet, the percentage of individuals with basic or above basic digital skills, and the percentage of individuals using the Internet for online courses. The data is reported for the year 2022, except for the indicator on digital skills, which is reported for 2021. The fourth group of indicators pertains to enterprises, including the percentage of enterprises that received orders online, the percentage of enterprises using software solutions to analyse client information for marketing purposes, the percentage of individuals who made internet purchases, and the percentage of turnover from e-commerce. The data is reported for the year 2022, except for the indicator on software solutions, which is reported for 2021. The final group of indicators pertains to research and development, including the percentage of GDP spent on R&D, the percentage of government expenditure allocated to R&D, and the percentage of the population in the labour force working in R&D positions. The data is reported for the year 2020 for R&D expenditure and R&D personnel, while the data for government budget appropriations or outlays is reported for 2021.

Table 1

Data classification and availability

Group	Indicator	Year	Unit of measure
Macro	Main GDP aggregates per capita	2022 (exc. Luxembourg 2021) estimate	Current prices, EUR per capita
Digital infrastructure	Level of Internet access-households	2022	% of households
Individuals	Internet use by individuals	2022	% of individuals
	Individuals who have basic or above basic overall digital skills	2021	% of individuals
	Individuals using the Internet for doing an online course	2022	% of individuals
Enterprises	Enterprises having received orders online	2022	% of enterprises
	Enterprises using software solutions, like CRM to analyse information about clients for marketing purposes	2021	% of enterprises
	Internet purchases by individuals	2022 (exc. Finland 2021)	% of individuals
	Share of enterprises' turnover on e-commerce	2022	% of turnover

Table 1 (continued)

Group	Indicator	Year	Unit of measure
R&D	R&D expenditure	2020	% of GDP
	Share of government budget appropriations or outlays on R&D	2021	% of government expenditure
	R&D personnel, numerator in full-time equivalent (FTE)	2020	% of population in the labour force

The indicators were further used in this study for calculating the factor analysis and regression analysis described further in the Results and discussion section, this was done by using the SPSS software.

Results and discussion

To identify the dimensions of the digitalisation of EU economies, the factor analysis was applied, namely principal component factor analysis. For measuring sampling adequacy the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity was taken into account to proceed to factor analysis. The result of the KMO = 0.769 > 0.5, meaning that the sample is adequate. Bartlett's test significance is the p-value (Sig.) of 0.000 < 0.05. These results indicate acceptable data adequacy, i.e. the data are sufficient and suitable for conducting factor analysis that is supported by the significant Bartlett's test and is applicable to the selected variables. Hence, the sample is adequate, and the factor analysis is valid [21; 22].

Therefore, the total variance to assess the factor structure could be examined. For identifying the number of factors, the extraction method of the principal component analysis and the Kaiser criterion were used. Two factors were extracted, which met the criterion that factors have eigenvalues larger than 1. Two factors explain 69.32% of the cumulative variance in digitalisation and R&D performance. The first factor explains 56.82% of the variance, the second factor explains 12.50% of the variance.

The principal components were revealed based on the method of the Varimax orthogonal rotation. Table 2 shows the factor loads for the two selected factors after rotation. Each factor consists of variables that have factor loads greater than 0.5 and contribute to the factor structure.

Table 2

Rotated component matrix

Indicators	Component	
	***F*1**	***F*2**
Level of Internet access-households	0.789	0.247
Internet use by individuals	0.799	0.417
Individuals who have basic or above basic overall digital skills	0.767	0.427
Individuals using the Internet for doing an online course	0.772	0.196
Enterprises having received orders online	0.604	0.242
Enterprises using software solutions, like CRM to analyse information about clients for marketing purposes	0.788	0.060
Internet purchases by individuals	0.627	0.628
Share of enterprises' turnover on e-commerce	0.470	0.512
R&D expenditure	0.198	0.885
Share of government budget appropriations or outlays on R&D	0.176	0.829
R&D personnel	0.285	0.885

The extraction method was the Principal Component Analysis and the rotation method was Varimax with Kaiser normalization.

Based on the indicators, the *F*1 (Component 1) could be labelled *Digitalisation level* and includes the following indicators: Level of internet access (0.789), Internet use by individuals (0.799), Individuals basic digital skills (0.767), Individuals using the Internet (0.772), Enterprises having received orders online (0.604), Enterprises using CRM (0.788), Internet purchases by individuals (0.627) and Share of enterprises' turnover on e-commerce (0.470). All factors are positively correlated with *F*1. *F*2 (Component 2) could be labelled *Research and Development* (*R&D*) which is positively correlated with R&D expenditure (0.885), Government budget on R&D (0.829) and R&D personnel (0.885) (see Fig.1).

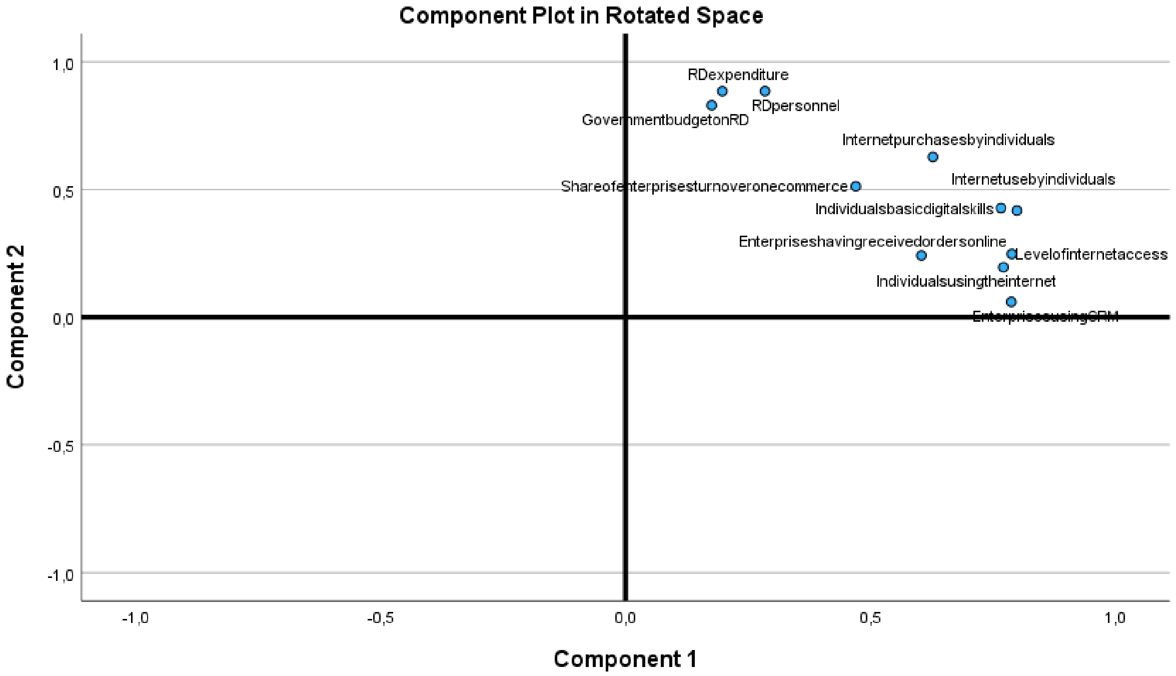

Fig. 1. **Components after rotation**

For exploring the contribution of the independent variables Factor 1 and Factor 2 (factors of the Digitalisation and R&D performance of EU economies) to the dependent variable GDPc (GDP per capita), i.e. the impact of these factors on the economic growth, the Enter method of multiple regression analysis was applied:

$$GDPc(\text{estimate}) = b_0 + b_1\,F1 + b_2\,F2 \qquad (1)$$

According to the regression results, it can be concluded that regression models are significant $F(2, 24) = 12.22$, $p = 0.000 < 0.05$, $R^2 = 0.504$.

The largest contribution to the dependent variable GDPc comes from *F*1 (Digitalisation level), then *F*2 (R&D). The regression unstandardized coefficients are: $b_0 = 29172.22$, $b_1 = 10876.07$ and $b_2 = 7950.18$, Standardized coefficients are $\beta_1 = 0.573$ and $\beta_2 = 0.419$ and all regression coefficients are statistically significant ($p = \{0.000,0.001,0.008\} < 0.05$).

Table 3

Theoretical GDP per capita based on the regression equitation for the Baltic States

Countries	***F*1**	***F*2**	**GDP theoretical, euro per capita**	**Main GDP aggregates, euro per capita**	**Difference, euro per capita**	**%**
Estonia	-0.03488	0.1404	37894.36	27170	10724.36	39.47
Latvia	-0.21799	-1.30767	21540.18	20720	820.18	3.96
Lithuania	-0.02028	-0.8204	28879.59	23620	5259.59	22.27

The regression equation that was obtained enables the calculation of Latvia's hypothetical GDP if it were to achieve the average level of digitalization and R&D in EU. It also allows for an assessment of the difference between the actual GDP and the hypothetical GDP. Table 3 reflects these differences for the Baltic States indicating that the increase in the theoretical GDP per capita for Latvia would be 820.18 EUR or 3.96%, for Lithuania it would be 5259.59 EUR and in Estonia it would reach 10724.36 EUR per capita or 39.47%.

Conclusions

1. To determine the digitalisation and R&D factors influencing EU economies the factor analysis, namely the principal components analysis was applied. According to the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity, the conducted factor analysis is reliable and allowed to identify the orthogonal dimensions digitalisation, namely F1 Digitalisation level and F2 level R&D.
2. The regression model obtained allowed to reveal the factors of digitalisation that can impact economic growth. It indicated that F1 digitalisation level and F2 R&D significantly contributed to GDP per capita and are the determinants of economic growth in EU member states. The obtained model also allows to calculate the hypothetical GDP if the particular EU country were to achieve the average level of digitalization and R&D in EU and the difference between the actual GDP and the hypothetical GDP. For Latvia such optimisation of digitalisation and R&D indicators would result in the growth of the GDP per capita till 820.18 EUR or 3.96%, for Lithuania it would be 5259.59 EUR and in Estonia the GDP per capita would reach 10724.36 EUR per capita or 39.47%.

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Author contributions

Conceptualization, S.ZR., methodology, S.ZR. and P.R; software, S.ZR. and P.R; data analysis, S.ZR. and P.R; data curation, S.ZR., writing—original draft preparation, S.ZR. and I.G., writing – review and editing, S.ZR., visualization, S.ZR., project administration, I.G., funding acquisition, I.G. All authors have read and agreed to the published version of the manuscript.

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