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REGIONAL DIGITAL ECONOMY IN THE DANUBE MEMBER STATES UNDER THE IMPACT OF THE NEW CHALLENGES

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Abstract. The paper aims to analyse the changing economic structure and the trends of the digitalization amplification through the prism of a dynamic multi-criteria model, assessing the strategic perspective by pivoting digitalization in the strategic equation. The main objectives of the research cover the context of vulnerability across the EUSDR countries, the solutions from the literature review and the definition, testing and implementing of a new dedicated model. The model takes into account regional indicators, reported by Eurostat. Statistical analysis procedures and methods were applied in order to capture the expected disparities under the impact of the pandemic, as well as harmonization with European Strategy for Danube Region (EUSDR) – specific impact indicators. The analysis uses la latest official statistical data from Eurostat. The importance of this scientific approach lies in the fact that the results are applicable to the wider region, the vast majority of the Danube states being EU members (9 states), 3 candidate states and 2 potential candidate states in the new geo-political and military context. States that are not yet EU members have regional and cross-border cooperation agreements with the EU. Moreover, the region itself has reacted in a unified way to the challenges of the economic and pandemic crises, the study being conducted over the period 2004–2020. In addition, EU Member States have additionally benefited from European emergency allocations to counter the effects of the global economic crisis and stem the spread of the pandemic. We used empirical and analytical methods, starting with the study of literature, data collection and consolidation of the database, its homogeneity and the application of modelling procedures. The major key findings are focused on the existence of a strong connection between investment effort, labour skills, sustainable development and the digital economy able to face new global and regional challenges. The policy implication of this research consist in offering viable elements capable of assisting regional decision-makers in adopting topical measures on digitisation and reconfiguring strategic regional connections to maintain a sustainable direction for the EUSDR. The recommendations from this study imbraca forma some directions for action related to labour high skills, digitalization, R&D investment and e-commerce.

Keywords: smart development, EUSDR, regional digital economy, dynamic model.

JEL Classification: R11, R12, R19.

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Introduction

The new atypical challenges for the EU27' economy supported the defying and the implementation of a new concept: smart development. The smart development implies the using of the latest environmentally friendly technologies in order to promote better economic development and the improving of the life quality. In order to realise these, the EU27 increased the investments in R&D which are able to give a realistic answer to the regional and global challenges.

The EU's dedicated actions are based on the European Commission's political guidelines for the period 2019–2024 (European Union, 2019). These political guidelines talk about: A European Green Deal; A Europe fit for the digital age; An economy that works for people; A stronger Europe in the world; Promoting our European way of life; and A new push for European democracy.

The European Green Deal represents a new development strategy able to transform EU27 into a fair and prosperous society with a modern, competitive and resource-efficient economy, with no net greenhouse gas emissions by 2050. In such economy, the environment and the health of citizens are protected and the economic growth is decoupled from the use of resources. The main targets of this Deal for 2030 are: a reduction of at least 40% in greenhouse gas emissions (compared to 1990 levels), a share of at least 32% in renewable energy and an improvement of at least 32.5% of energy efficiency. In order to achieve them, 260 billion euros will be extra invested.

There are three different sources for financing the investment plan for a sustainable Europe:

- EU's budget: sustainable investment of at least 1 trillion euros over the next decade. They will come from greater public expenditures on climate and the environment and private funds regarding guarantees;
- a favourable environment for private investors and the public sector: the financial institutions and private investors must have the necessary tools to properly identify the sustainable investments, while the public sector has to realise proper identification of the investment needs;
- a provide tailored support to public administrations and project promoters for the identification, structuring and execution of sustainable projects (European Commission, 2020a).

As a result, the EU research-intensive regions have the opportunity to be placed around universities, high-technology industries/services which were able to attract a lot of highly qualified labour. This is why the gross domestic expenditures on R&D achieved 280.3 billion euros across the EU27 in 2017 (Kotzeva et al., 2020).

Given the defined above context, the EUSDR is an effective tool for sustainable regional development which respects the Green Deal and the EU's long-term objectives in this field. However, under the impact of the new global and regional challenges, the EUSDR proves not to be able to mitigate the regional socio-economic disparities between the Danube Member States, diminishing the potential of the common strategy and the results which can be achieved through its implementation in line with the conditions imposed by the present crisis. In this regard Svarc et al. (2020) analyse the state of implementation of the European

Smart specialization strategy, which ensures European Smart specialization strategy, which provide resources for science, technology and innovation. Moreover, the authors stress the need to find a new innovation paradigm.

The aim of the present research is to develop a multi-criteria model for optimizing and improving the regional performance of the EUSDR states from the perspective of digitalization in the context of present uncertainty.

The *research objectives* are mainly aimed at:

O1: Establishing the context of vulnerability currently affecting the EUSDR countries;

O2: Literature review in order to identify possible models for improving and scientizing EUSDR in the context of digitization and the start of Covid-19 pandemic;

O3: Determination of the multi-criteria dynamic model based on regional results reported over the last 17 years by the Danube Member States;

O4: Piloting the dynamic model and proposals for increasing regional performance based on model results.

In the literature, there is a predominantly pragmatic orientation at the regional level related to regional disparities and less oriented towards identifying the nuances of linking vulnerabilities with the real opportunities provided by EU macro contexts in Europe and globally. We consider our scientific approach as a real contribution to the need to solve regional problems by providing a tool to quantify disparities in the context of regional smart sustainable development.

The novelty of the present scientific approach consists in correlating the specific indicators with the new opportunities and threats in the Danube region in the context of digitalization and pandemics and outlining a scenario for improving the strategy based on statistically validated results.

The innovative value of our contribution lies in the quantification of disparities in dynamics, which allows the monitoring of regional development policies and their correction through effective measures with improved prospects of achieving the strategic targets proposed at Community level (integration of regions into macro-regions).

1. Previous research on the subject

The smart development concept is very popular across the dedicated researches. The latest representative papers are selected in this chapter.

An interesting paper is focused on smart specialization as a support for the economic diversification and cover the Scandinavian regions. The authors define the smart specialization as a new policy able to develop the existing or the potential competitive advantage which differentiates a region from others. Basically, the smart development ensures existing and future competitiveness. The research covers regions from Denmark, Sweden, and Norway and points out the connection between the smart concept and innovation and knowledge (Asheim et al., 2017). We consider this approach to be fair and of regional impact.

The same implication of the researcher specialization in the current context in a Danube Member State (Romania) is also addressed by some authors (Drăgan et al., 2021) who refer to the entrepreneurship in the eco-label industry and analyze a wide range of countries. As

a result of this scientific approach is the conclusion that the research experience and the personal attitude have a positive effect on the entrepreneurship education for the sustainable development. We appreciate this less common approach to regional development.

According to some experts (Gänzle et al., 2019), the EUSDR has shown a greater openness towards strengthening cooperation with non-EU member states, based on transnational cooperation and transnational unions created within the EUSDR. This is an impact factor for the strategy. In this context, several institutions have been drawn into this strategic cooperation: National, Crossborder Cooperation and Multi-beneficiary country programmes and several (European Neighbourhood Policy Instrument – ENPI) programmes.

For one of the Danube countries (Slovakia), the regional competitiveness indices were calculated in terms of sustainable environment, transit policy in the area, infrastructure and cultural factors. According to the authors, Slovakia occupies one of the last two places in the regional competitiveness ranking (27), followed only by Romania (28), while Germany ranks 3rd, Austria 6th, Bulgaria 21st and Hungary 23rd (Bednárová et al., 2018; Gabor et al., 2021). A similar approach is presented in this paper.

According to some authors (Cristache et al., 2019), the improving of the economy's sustainable climate and thus the increasing of the regional interest can be achieved by building an economic strategy that engages Small and Medium Enterprises (SMEs), according to the implementation of the code of corporate responsibility, which will ultimately allow an economic development of the area by increasing the local business component. In this context, the authors define six working hypotheses according to which there are multiple correlations between the social responsibility of firms and their strategic objectives, including sustainable economic development. Moreover, the authors find a direct link between social responsibility and capitalising on opportunities for efficient resource allocation, which leads directly to economic sustainability. The approach itself seems to be outdated under the current new regional challenges.

A different approach is that which is focused on the smart specialisation strategies. It puts under discussion the innovation policies and regional innovation systems as instruments of promoting the international competitiveness and economic growth. Moreover, the analysis covers the unrelated knowledge combinations and the new path creation which support the increasing of the complexity of the technology and the knowhow. The analysis is applied to a moderate innovative Eastern European region (Mazovia), (Asheim, 2019). As there are different levels of implementation of smart specialisation strategies, difficulties of cooperation between countries arise.

The European policy of implementing the smart specialization policy is criticised using the lack of a coherent set of analytical tools to guide this policy. For the EU regions is very difficult to accomplish the diversity of the new complex technologies. The main result of this analysis is the building of a framework able to highlight the potential risks and the rewards for regions of adopting the competing diversification strategies (Balland et al., 2019). We believe that, at least at this moment, the risks are very high for the implementation of the smart specialization policy.

The Smart Specialisation and Industry 4.0 are presented as main instruments for the regional revitalising. A dedicated book was focused on the lowest developed regions (lagging

regions) in order to point out the perspectives of the Smart Specialization Policies on this kind of regions' development. There are case studies which covers regions from Eastern Europe, including Poland and Slovenia. The last chapter of the book presents the future of the place-based innovation policy in the EU (Barzotto et al., 2019).

The analysis of EUSDR implementation over the period 2011–2018 was carried out by Gänzle and Mirtl (2019) through an experimental study on governance between European regions in territorial cooperation. In methodological terms, the paper is based on the analysis of 38 semi-structured interviews of EU MRS, EUSBSR and EUSDR actors. The author's conclusion reflects the fact that all four strategies share common elements of the governance architecture. The thematic coordinators have been established as central pieces. The EUSDR has been reducing in importance recently. The rotation of the thematic area coordinators ordered by the European Commission in 2016 is an objective to monitor and boost the development of the EUSDR.

Some authors (Pagliacci et al., 2020) considered relevant for the future of the cohesion policy the analysis of the heterogeneous structure of the involvement of the R&D&I strategy introduced in 2014–2020, through an impact analysis of specific economic and demographic components in 19 types of European regions. The authors point out that, after the creation of the EUSDR in 2011, several types of clusters were created, which defined developed versus developing regions, including the agricultural sector. EUSDR is the most concentrated form of the economic differentiation clusters (7) compared to EUSAIR (10), indicating a concentration of the diversity index at the level of the core entities in the region. We find the cluster approach viable and interesting.

According to Cepoi (2021), the Europe 2020 Strategy is a strategy for responding to the economic crisis and restarting the European economies. The author proposes an economic reconfiguration of the Danube region with an assessment of the consequences on the EUSDR strategy through digital transformation techniques and HPC (High Performance Computing). From the priority areas point of view, the author re-evaluates the cultural-political economy segment on which he assesses the possibility of improving strategies based on the inventory of social trends in relation to existing operational structures. In terms of knowledge society and knowledge economy segments, the author identifies priorities such as: refocusing R&D&I on the current major challenges and differences between the market and the economy; setting a digital agenda for Europe; establishing a green sustainable growth policy and activating the European platform against poverty and social exclusion. At the level of the 4 strategic pillars of the EUSDR the challenges identified by the author are: connecting the Danube regions on all strategic segments (transport, energy, culture and tourism); environmental protection in the Danube region; building a prosperous Danube region by increasing education, skills and reducing marginalised communities; strengthening the institutional capacity for cooperation to achieve a stronger Danube region. We appreciate this approach, which we also partly used in our analysis.

A possible connection between the territorial cohesion and the smart regions is put into discussion using the demand for information and communication technology (ICT) infrastructure. Finally, all regions represent a correlation between urban and rural areas and will be difficult for the decision makers to eliminate the disparities between them. The authors

of this research recommend the using of the three components (discourse, implementation and regulation) in realising the smart regions (Matern et al., 2020).

The smart rural regions represent, under another approach, the valorisation of the local challenges and opportunities. The rural regions present different characteristics than the urban regions, which are connected to depopulation, economic undeveloped capacities, less wealth and less ability to attract investment. As in the previous paper, the authors propose as solution the Information and Communication Technologies (ICT). This approach is applied to the Northeast region of Portugal. The results of this research are used in order to build a model of smart rural region (Cunha et al., 2020). The model itself has limitations that its authors acknowledge from the outset.

The connection between a smart urban centre and the environment are studied in the case of Reykjavik. The analysis is based on two concepts: "SMART" cities and "SMART" specialisation. According to this concept, a smart city strategy would cover actions able to develop the city and to ensure welfare for its citizen, but to protect and to improve environment, to another hand. Such an interactive innovative ecosystem is modelled using a triple and quadruple helix system. A solution for such development can be the building and implementation of knowledge and innovation clusters in the analysed city (Josefsson & Steinthorsson, 2021). We believe that the smart development approach is much better argued in Northern European countries than in EUSDR countries.

According to the INTERREG report for the implementation of the EUSDR (European Commission, 2020b), the achievements on the 4 pillars and 11 priority areas consist of: improving regional administrative support to strengthen regional capacity for infrastructure access and cooperation; establishment of the priority area coordinators; improving financing by creating dedicated financing instruments; strengthening the commitments of the national ministries by sector of activity; creation of the national mechanisms able to coordinate and improve EUSDR regional integration; creating an investment platform to promote the needs of the local and regional business environment; dialogue between partners at all levels.

According to European Commision (2020b), the EUSDR strategy is analysed in terms of implementation results in 2019, with a satisfactory success rate (out of 95 mainstream ESI Funds programmes, Interreg and IPA-CBC programmes, and IPA II mainstream, 62, respectively 65%). At the level of the countries analysed, the success rates of the projects included in the EUSDR strategy were: Austria 25%, Bulgaria 70%, Germany 56%, Hungary 77%, Romania 62% and Slovakia 38%.

Some authors, analysing sustainable development with reference to the 4th industrial revolution, appreciate that the EUSDR macro-regional strategy, more specifically Inland Waterway Transport, must be based on relevant objectives, given the current challenges of the Danube River. According to the authors, a sustainable direction would be to increase shipping volumes in the macro-region (Nagy et al., 2020). Moreover, they note the existence of large disparities between Member States, which divide the Danube macro-region into two regions: rather active countries (Germany, Austria, Slovakia and Romania) and moderately active countries (Hungary and Bulgaria). The disparities between the EUSDR states were also highlighted in our analysis.

In the paper by Mönning (2020), the author analyses Eastern European economies through a parallel between the Europe 2020 strategy and the EUSDR. Moreover, the author

compares the economic policy objectives between the strategies and assesses the elements of differentiation between them based on the challenges of the two types of processes. The author concludes that the EUSDR seeks to complement the Europe 2020 strategy, with reference to the knowledge – based economy. EUSDR focuses on reducing unemployment, rural underdevelopment and generally increasing the attractiveness of the regional area. We consider the capacity to implement European policies much lower in the case of EUSDR.

One solution for the sustainable development of the Danube macro-region is the promotion of SMEs as part of the EUSDR priority areas. The authors carry out an impact study on this issue in a Danube country (Romania) and highlight the impact of economic activity on the environment based on a questionnaire addressed to forestry companies. The study carried out is useful for stakeholders as it enables them to identify the risks and threats associated with the sector and the market in a developing Danube economy (Socoliuc et al., 2020).

The smart regional development is analysed based on the connection between the regional capabilities and the Smart Specialisation Strategy. According to this, the interregional linkages are important in the development of the 292 NUTS-2 regions from the EU27. In this manner, the importance of the connections to other regions that provide complementary capabilities increases. Moreover, the authors of this research defined a new indicator to identify other regions as strategic partners in their S3 policy (Balland & Boschma, 2021).

From other point of view, the smart approaches can lead to faster development of the less developed regions. The authors point out the importance of the collaborative networks in developing the peripheral regions. This means a new theoretical conceptualization and better defining and implementing of the regional policies and governance models, as well (Ferreira et al., 2021).

A careful analysis of the policy documents related to the EUSDR is carried out by Csizmadia (2021). These documents (Communication of the Council and the Action Plan) cover the general principles of the EUSDR but also the policy guidelines for the participating actors. On the other hand, the author presents in detail the Policy goal-setting of the EUSDR until 2030, structured on 4 pillars and 11 priority areas in line with the thematic objectives of the Common Provisions Regulation (Art. 9 (EU) No 1303/2013).

The prospects of achieving an equitable, environmentally sustainable, and healthy society are quantified by Mondejar et al. (2021) from the perspective of digitalization. The authors consider that an important component of regional development is smart technologies applied in food-water-energy nexus. The paper concludes that the benefits of digitisation are linked to the transition to sustainable manufacturing practices and to providing digital access to care.

The connection between cooperation in decision-making and spatial development is analysed by Purkarthofer et al. (2022), with direct reference to the EUSDR, which is seen as "functional space". The authors point out that managerial functionality exists at the level of EUSDR member states, whether or not they are members of the EU. The key actors in the EUSDR are national stakeholders which created links with funding programmes, while European Commission ensures coordination, mediation and communication services.

The visibility of the EUSDR and thus of the Danube was tested by Padło et al. (2021), based on questionnaires for students from different European countries. The general percep-

tion was that EUSDR is much better known in Central and Eastern European countries than in Western European cities.

The causal relationships between carbon emissions, energy consumption and economic growth were analyzed by Litavcová and Chovancová (2021). The analysis covers 14 Danube region countries over the period of 1990–2019 and is based on the ARDL approach. The analysis shows a good correlation of the analysed indicators for Austria, Czechia, Slovakia, and Slovenia.

EUSDR has also been analysed in relation to the concentration of electronic retail by Končar et al. (2022), who highlights differences in the level of development of the retail market and electronic retailing across the states. The authors highlight a significant relation between the origin and types of retailers and the degree of concentration of electronic retail.

The development of e-commerce at EU level is not as evident in all EUSDR countries. These states have to fight against non-harmonized regulations and poorly developed individual markets according to the opinion of Končar et al. (2021). While Germany and Austria present significant volumes of e-retailing, Bulgaria and Romania are at the forefront. We believe that the differences in development between these four Danube countries will persist at least in the medium term.

From the digital economy point of view, an interesting approach by Miao (2021) considers digital economy value chain. According to this approach, there are two categories of activities (Primary Activities and Support Activities), which cover a multitude of aspects such as: Infrastructure, Human Resource Management, Technological Development, ICT Procurement, Digital Marketing, Digital Connectivity and Digital Production.

A synthesis of the research directions in the literature regarding regional disparities (see Figure 1) was carried out by the authors through a study conducted on the Web of Science platform on a number of 281 publications carried out in the period 1975–2022, of which 122 publications were carried out in the period 2018–2022 and were highly rated (5695 citations), with an average citation rate of 22 citations/item and a Hirsch index of 35 points.

From Figure 1, a number of 5 clusters can be observed in which interest is divided between disparities based on regional variations and related to regional development policies, disparities based on convergence, geographical disparities and financial disparities generated by fiscal decentralisation and spatial inequalities and poverty.

In the case of the digital economy, 71 articles published in the period 1975–2022 were analysed, of which 59 were published in the period 2018–2022, articles that enjoyed high recognition accumulating a total of 996 citations, with an average of 14.51 citations per item and a Hirsch index of 18 points (see Figure 2).

The study conducted on the Web of Science platform highlights the research interest in the digital economy on 4 clusters oriented towards interconnections with the circular economy, industry 4.0 and sustainability, e-commerce and digital transformation and technological innovation, sharing economy, communications, digital platforms and science. The last branch is oriented towards social media, big data, digital labour and political economy.

All the above approaches lead to the conclusion that is necessary a new way of scientific investigation regarding the regional development under the presence of the smart development solutions.

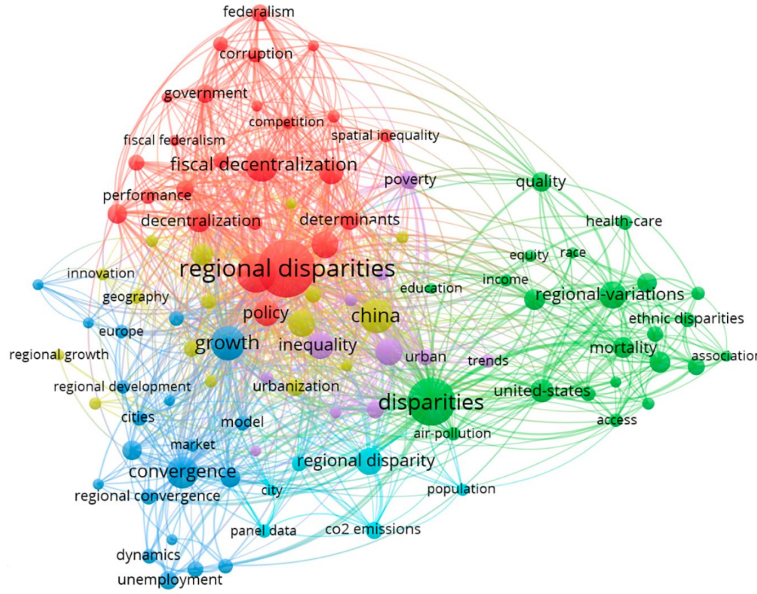

Figure 1. Analysis of regional disparities focus areas (source: Web of Science and VOSviewer)

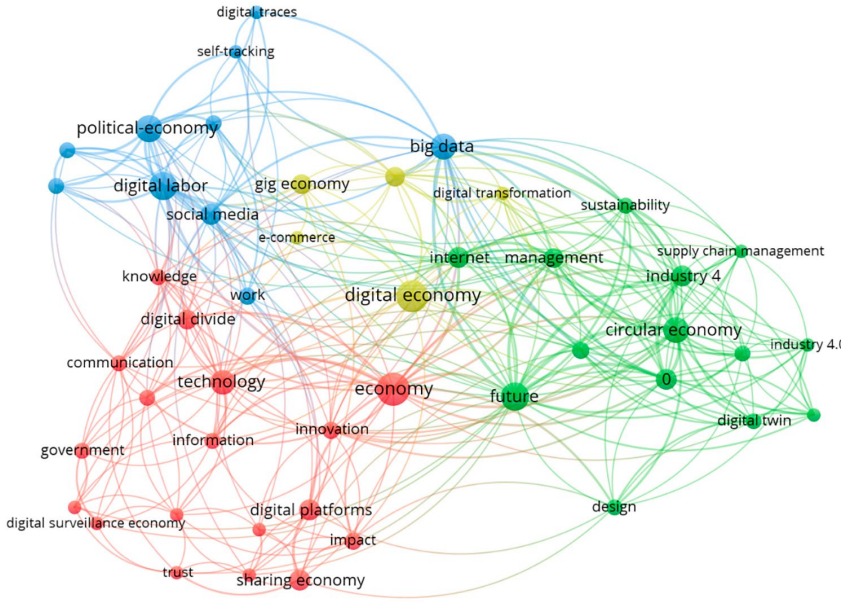

Figure 2. Analysis of digital economy focus areas (source: Web of Science and VOSviewer)

This is why, we propose a distinct analysis in this field using the latest official statistical data, pertinent tables and diagrams. The analysis covers the NUTS2 regions from the EU Danube Member States.

2. Methodology

In this Section, we describe the detailing of the logical sequences followed to build the model, as follows. We have selected regional indicators specific to digitisation and sustainable development from Eurostat databases. These indicators have been analysed in dynamics over the period 2004–2020. During this period, data collection has been uneven, including against the backdrop of the last two waves of EU accession, which did not allow the consolidation of the database with values for each indicator until the period 2014–2020, which coincides with the recovery from the economic crisis, by which time the digital component was already crystallized and the policy to develop this component was being implemented and producing effects throughout the EU.

The studied indicators and their constructive structure are:

- Regional Gross Domestic Product (GDPR) at current market prices by NUTS 2 regions; UNIT: Million euro NUTS2 region/ Million euro European Union – 27 countries (from 2020); Data extracted on 04/10/2021 14:20:12 from [ESTAT] (EUROSTAT, 2020);
- Intramural R&D expenditure (GERD) by sectors of performance and NUTS 2 regions; UNIT: Euro per inhabitant of the NUTS2 region/ Euro per inhabitant of European Union – 27 countries (from 2020); Data extracted on 04/10/2021 14:25:44 from [ESTAT] (EUROSTAT, 2020);
- HRST by category and NUTS 2 regions; CATEGORY: Persons with tertiary education (ISCED) and/or employed in science and technology; UNIT: Percentage of active population; Data extracted on 04/10/2021 14:40:40 from [ESTAT];
- Individuals who used the internet, frequency of use and activities (INDICIS); CATEGORY: Frequency of internet access: once a week (including every day); UNIT: Percentage of individuals; Data extracted on 04/10/2021 14:45:20 from [ESTAT] (EUROSTAT, 2020);
- Individuals who used the internet for interaction with public authorities (INDICADM); CATEGORY: Internet use: interaction with public authorities (last 12 months); UNIT: Percentage of individuals; Data extracted on 04/10/2021 15:40:23 from [ESTAT];
- Individuals who ordered goods or services over the internet for private use (ISOC); CATEGORY: Last online purchase: in the last 3 months; UNIT: Percentage of individuals who ordered goods or services, over the internet, for private use, in the last year; Data extracted on 04/10/2021 15:48:33 from [ESTAT] (EUROSTAT, 2020).

These indicators were adapted according to the Unitary Mode of Representation (UNIT) in order to make the projections in the database in percentages, which increased the unitary reporting of the database and the model's relevance.

The cumulative regression model, based on the two-stage least squares regression, pivots the sustainable development component reflected by GDPR (dependent variable) on the

digital component represented by the five indicators – regressor variables (GERD, HRST, INDICIS, INDICADM, ISOC) in dynamics, for each and during the analysis period. This approach allowed the seasonal configuration of regressor distribution plots against the dependent variable (GDPR) and the assessment of the sustainable economy dynamics in the digital age within the EUSDR.

In order to study the phenomenon of sustainable regional development in the context of digitization in the Danube area, we propose the following *working hypotheses*:

H1: The sustainable regional development is enhanced if and only if the investment effort represented by Intramural R&D expenditure is intensified and homogenised across the entire Danube macro-region. This hypothesis is supported by the researches of B. Asheim et al. (2017), Gänzle et al. (2019), Kotzeva et al. (2020), Pagliacci et al. (2020).

H2: Increasing the share of science & technology skilled labour on the basis of a viable funded strategy can be a risk prevention factor in case of major events to prevent macro-regional structural imbalances and allow further sustainable development. This hypothesis is supported by the researches of B. T. Asheim (2019), Cepoi (2021), Cunha et al. (2020), Matern et al. (2020).

H3: Internet use for personal purposes is an indicator with a lower contribution to sustainable development, being vulnerable to the onset of the pandemic and generating disparities in the sustainable development in relation to the EU's digital policy objectives. This hypothesis is supported by the researches of Cepoi (2021), Cristache et al. (2019), Cunha et al. (2020), Drăgan et al. (2021), Matern et al. (2020).

H4: Digitization of the public administration and its connection with the citizens is an asset of smart development, under the conditions of changing the mentality of approaching the system (an aspect which has become urgent during the pandemic). This hypothesis is supported by the researches of B. Asheim et al. (2017), Barzotto et al. (2019), Bednárová et al. (2018), Gabor et al. (2021), Gänzle and Mirtl (2019).

H5: Sustainable development depends on fostering the digital economy in a manner of information security and regulatory balance which prevents vulnerabilities related to the volatility function of the digital economy. This hypothesis is supported by the researches of Balland et al. (2019), Josefsson and Steinthorsson (2021).

$$S_{tr} = \sum_{r=1}^{52} R_r * \left(\frac{\sum_{t=1}^{n} \sum_{i=1}^{m} \left(\propto_{it} * D_{it} + \varepsilon_t \right)}{\sum_{t=1}^{n} t} \right), \quad (1)$$

where S_{tr} – sustainability of seasonal influence at EUSDR macro-region level; R_r – the coefficient for each EUSDR region; $R_r < 1$, $\sum_{r=1}^{52} R_r = 1$; r – number of EUSDR regions; t – the number of years for which the seasonal projection is made; i – the number of variables assimilated to the regressors of the model and which measure the digital economy; μ_{it} – the value of the regression coefficients of the variables calculated from the two-stage least squares regression in each year t of the analysis; D_{it} – value of the regression variable i in year t; ε – the value of the residual variable in year t.

The obtained results methodologically motivate their applicative dissemination in the results section.

3. Results of the research

Based on the general model, the regional sustainability function values were tested annually and the following results were obtained (see Table 1).

The regional sustainability component in 2014 (S_{2014r}) in relation to the regressors related to digital economic development generated a high level of statistical significance of 80% for a coefficient of determination $R^2 = 82.1\%$ and a standard error of the estimator of 23%, which in relation to the distribution averages of economic development represents about 30% of the general level of evolution on average of the indicators of digitization whose dynamics at the level of 2014 is between 37–90% compared to the general averages of evolution calculated at EU level. For the EUSDR macro-region, this means an economic recovery and a favourable context at the level of 2014, marked by the beginnings of cooperation within the EUSDR (see Figure 3). The positive effects of EUSDR cooperation have also been highlighted by Bednárová et al. (2018), Drăgan et al. (2021), Gabor et al. (2021), Gänzle et al. (2019) as well.

Table 1. Seasonal sustainability function for 2014

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
2014	0.906[a]	0.821	0.803	22.99355	0.821	44.094	5	48	0.000	1.278

Notes: [a]Predictors: (Constant), ISOC2014, GERD2014, HRST2014, INDICADM2014, INDICIS2014; [b]Dependent Variable: GDPR2014.

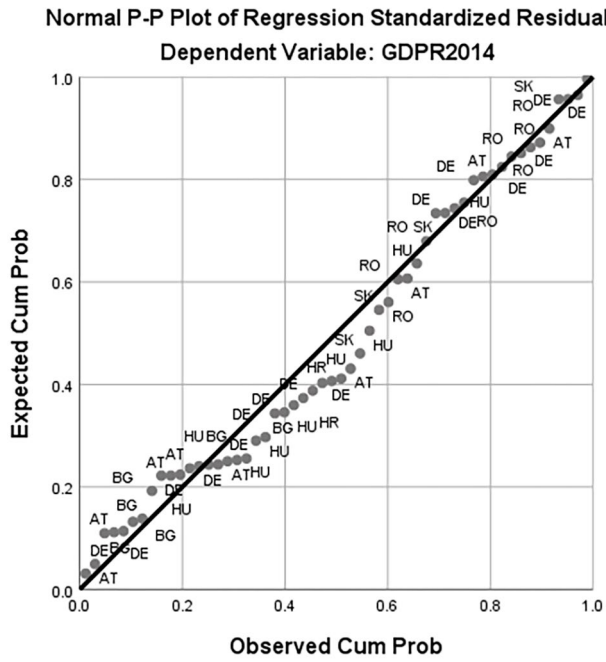

Figure 3. P-P Plot for sustainable development of EUSDR in 2014

From the above graph, it can be seen that there were differences between the regional economies of Germany, Austria and Slovakia compared to the trend line (y*– y), which can also be seen from the overall averages of the evolution of the digital economies in the region, of which the HRST component, INDICADM and ISOC manage to cumulate a score of no more than 43% of the European average. At the opposite pole are GERD and INDICIS, which managed to achieve a seasonal development performance of up to 90% of the EU average. This distribution shows that the R&D component and the use of the internet to expand connections and knowledge were the main areas of the digital economy on which the EUSDR countries carried out sustainable development actions in 2014.

From the ANOVA plot point of view, we find that the regression function is homogeneous and valid. The level of representation of the residual component in the sum of the regression squares is 17.8% and the level of representation of the degrees of freedom of the regression components is 5 out of 53 possible. In addition, we note an F-test of 44 points and a Sig coefficient tending to 0 (see Table 2).

The regional sustainability component in 2015 (S_{2015r}) in relation to the digital economic development regressors generated a high level of statistical significance of 80% for a coefficient of determination R^2 = 82.3% (up from 2014) and a standard error of the estimator of 22.5% (down from 2014). In relation to the distribution averages of the economic development, these represent about 30% of the overall average level of evolution of the digitization indicators whose dynamics in 2015 is between 38–86.5% of the overall averages of evolution calculated at EU level (see Table 3).

For the EUSDR macro-region, this means an improvement in the performance of the digital economy (especially in terms of online commerce – ISOC) and a context favourable to 2015 levels (see Figure 4).

Table 2. ANOVA test afferent to the model for 2014

Model		Sum of Squares	df	Mean Square	F	Sig.
2014	Regression	116564.163	5	23312.833	44.094	0.000[b]
	Residual	25377.753	48	528.703		
	Total	141941.915	53			

Notes: [a]Dependent Variable: GDPR2014; [b]Predictors: (Constant), ISOC2014, GERD2014, HRST2014, INDICADM2014, INDICIS2014.

Table 3. Seasonal sustainability function for 2015

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	0.907[a]	0.823	0.804	22.54942	0.823	44.620	5	48	0.000	1.297

Note: [a]Predictors: (Constant), ISOC2015, GERD2015, HRST2015, INDICADM2015, INDICIS2015; [b]Dependent Variable: GDPR2015.

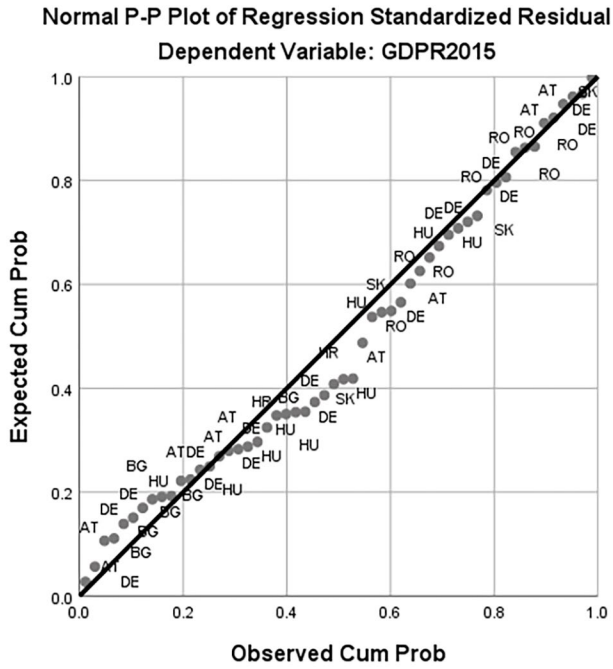

Figure 4. P-P Plot for sustainable development of EUSDR in 2015

According to Figure 4, Germany, Austria and Slovakia remain the poles away from the forecast right. One aspect directly attributed to the EUSDR strategy is that, as a result of the Germany-Romania and Germany-Hungary partnerships, these countries tend to enter in the sphere of influence of the poles, moving slightly to the right of foresight. Similar but less representative results were obtained by Bednárová et al. (2018), Gabor et al. (2021).

Specific to 2015 is the increase in online transactions and the beginning of the development of the digitization of public administrations. During this period, some best practice guides in the relationship with the taxpayer were created (Agentia Națională a Functionarilor Publici, 2015).

Also, since 2015, the correlation indicators of the digital efficiency of public administration in relation to the dependent variable GDPR have increased by 5% compared to 2014, i.e. a correlation of 73.8% in 2015 compared to 69.6% in 2014.

The trends of inversely proportional variation are maintained but with lower shares of GERD and HRST in 2015 compared to the previous year, with reference to e-commerce (ISOC).

From the ANOVA plot point of view, we find that the regression function is homogeneous and valid. The level of representation of the residual component in the sum of the regression squares is 17.7% and the level of representation of the degrees of freedom of the regression components is 5 out of 53 possible. It shows an F-test of 44.6 points and a Sig coefficient of 0 (see Table 4).

The regional sustainability component in 2016 (S_{2016r}) in relation to the digital economic development regressors generated a high level of statistical significance of 81.7% for a coefficient of determination R^2 = 83.4% (up from 2015) and a standard error of the estimator of 21.5% (down from 2015). Compared to the distribution averages of economic development, they represent about 35% of the general level of evolution on average of digitization indicators whose dynamics at 2016 level is between 38–88.5% compared to the general averages of evolution calculated at EU level (see Table 5). In the literature, this subject has aroused real interest in works such as those of Balland et al. (2019), Josefsson and Steinthorsson (2021).

For the EUSDR macro-region, this means improving the performance of the digital economy translated into the sustainable economy, reducing deviations from the Gaussian curve and reviving the use of the internet by individuals and businesses as a component of the digital economy. Although the topic is addressed in other research such as Cepoi (2021), Cristache et al. (2019), Cunha et al. (2020), Drăgan et al. (2021), Matern et al. (2020), our approach is more complex and better focused on the latest regional and global developments.

In the EUSDR countries, new Internet service distribution operators have been established and the regions with coverage in each country have been consolidated (see Figure 5).

According to Figure 5, Germany, Austria and Slovakia remain as poles of distance from the forecast right, but one aspect directly attributed to the EUSDR strategy is that, following the partnerships, Bulgaria tends to enter under the sphere of influence of the poles.

Also, in 2016, there is a maintenance of the correlation indicators of digital efficiency in relation to the GDPR dependent variable, registering an increase in the attraction of specialists in the R&D sector for the implementation of projects and programs funded in the EUSDR and EU strategic agreement.

Table 4. ANOVA test afferent to the model for 2015

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	113440.582	5	22688.116	44.620	0.000[b]
	Residual	24406.874	48	508.477		
	Total	137847.456	53			

Note: [a]Dependent Variable: GDPR2015; [b]Predictors: (Constant), ISOC2015, GERD2015, HRST2015, INDICADM2015, INDICIS2015.

Table 5. Seasonal sustainability function for 2016

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
2016	0.913[a]	0.834	0.817	21.48213	0.834	48.266	5	48	0.000	1.557

Note: [a]Predictors: (Constant), ISOC2016, GERD2016, HRST2016, INDICADM2016, INDICIS2016; [b]Dependent Variable: GDPR2016.

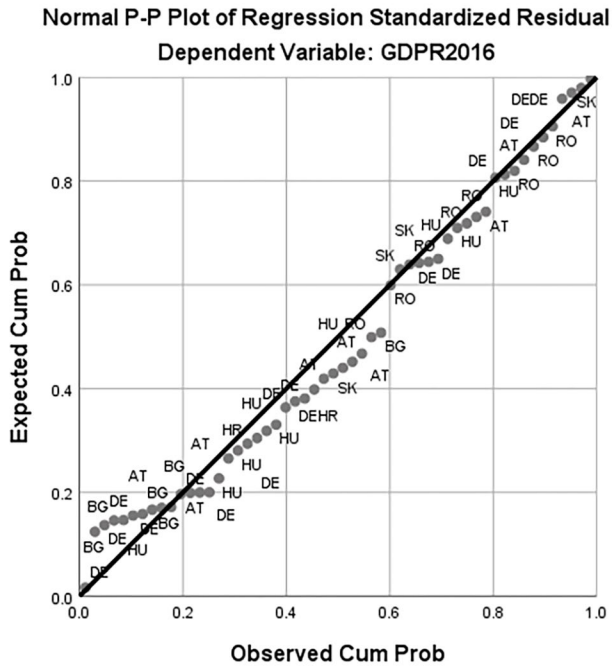

Figure 5. P-P Plot for sustainable development of EUSDR in 2016

From the ANOVA plot point of view, we find that the regression function is homogeneous and valid. The level of representation of the residual component in the sum of the regression squares is 16.6% and the level of representation of the degrees of freedom of the regression components is 5 out of 53 possible. This results in an F-test of 48.3 points and a Sig coefficient that tends to 0 (see Table 6).

The regional sustainability component in 2017 (S_{2017r}) in relation to the digital economic development regressors generated a high level of statistical significance of 83.4% for a coefficient of determination R^2 = 84.9% (up from 2016) and a standard error of the estimator of 20% (down from 2016). Compared to the distribution averages of the economic development, it represents about 35% of the overall average level of evolution of digitization indicators whose dynamics at 2017 level is between 39–85.5% compared to the general averages of evolution calculated at EU level (see Table 7).

For the EUSDR macro-region, this means an improvement in the performance of the digital economy translated into the sustainable economy, especially in the case of internet use by individuals for e-commerce (see Figure 6).

According to Figure 6, the trend line aligned with the seasonal regional development line of the poles. As a result, there are differences across Croatia and Romania. The rest of the analysed countries managed to adopt sustainable growth in relation to the digital development.

Moreover, in 2017, most of the correlations between the indicators related to digitization in relation to the GDPR dependent variable are increasing, registering an increase in online commerce on the sustainable dimension, a foundation of R&D. This means that one unit of economic growth relative to GDP is due to 0.8 units of R&D performed with 0.7 specialists

Table 6. ANOVA test of the model for 2016

Model		Sum of Squares	df	Mean Square	F	Sig.
2016	Regression	111369.484	5	22273.897	48.266	0.000[b]
	Residual	22151.140	48	461.482		
	Total	133520.625	53			

Note: [a]Dependent Variable: GDPR2016; [b]Predictors: (Constant), ISOC2016, GERD2016, HRST2016, INDICADM2016, INDICIS2016.

Table 7. Seasonal sustainability function for 2017

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
2017	0.922[a]	0.849	0.834	20.00420	0.849	54.128	5	48	0.000	1.655

Note: [a]Predictors: (Constant), ISOC2017, GERD2017, HRST2017, INDICADM2017, INDICIS2017; [b]Dependent Variable: GDPR2017.

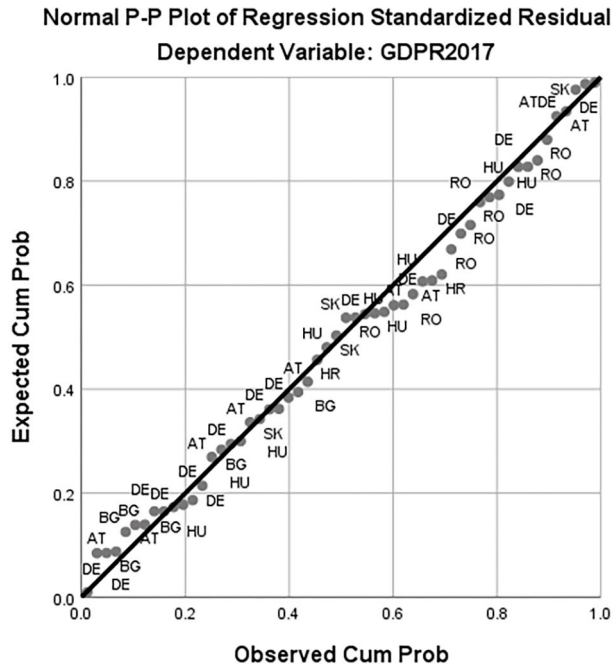

Figure 6. P-P Plot for sustainable development of EUSDR in 2017

attracted in related sectors on a 70% margin of e-commerce efficiency. In the literature, a significant place in sustainable development strategy is given to R&D orientation as an enhancing component in the context of the knowledge society (B. Asheim et al., 2017; Gänzle et al., 2019; Kotzeva et al., 2020; Pagliacci et al., 2020).

From the ANOVA plot point of view, we find that the regression function is homogeneous and valid. The level of representation of the residual component in the sum of the regression squares is 15% and the level of representation of the degrees of freedom of the regression components is 5 out of 53 possible. This results in an F-test of 54.1 points and a Sig coefficient of 0 (see Table 8).

The regional sustainability component in 2018 (S_{2018r}) in relation to the digital economic development regressors generated a high level of statistical significance of 81.5% for a coefficient of determination R^2 = 83.3% (slightly decreasing from 2017) and a standard error of the estimator of 20.6% (increasing from 2017). Compared to the distribution averages of the economic development, it represents about 30% of the general level of evolution on average of digitisation indicators whose dynamics at 2018 level is between 39.5–82.2% compared to the general averages of evolution calculated at EU level (see Table 9).

For the EUSDR macro-region, this means an improvement in the performance of the digital economy translated into the sustainable economy, especially in the case of internet use by individuals in their relationship with public administration and e-commerce. There has been a successive decline in the contribution of R&D in the sustainable development component, which can be justified by the completion of projects financed by non-reimbursable funds and the lack of action in terms of internal financing from own sources in the sector (see Figure 7).

According to Figure 7, the trend line is affected by inhomogeneities in the y^*–y distribution, with food safety impacts, namely the impact of swine fever, avian influenza, etc. (Antohi et al., 2019).

From the ANOVA plot point of view, we find that the regression function is homogeneous and valid. The level of representation of the residual component in the sum of the regression squares is 16.7% and the level of representation of the degrees of freedom of the regression components is 5 out of 53 possible. As a result, the F-test is 47.7 points and the Sig coefficient tends to 0 (see Table 10).

Table 8. ANOVA test of the model for 2017

Model		Sum of Squares	df	Mean Square	F	Sig.
2017	Regression	108301.745	5	21660.349	54.128	0.000[b]
	Residual	19208.060	48	400.168		
	Total	127509.805	53			

Note: [a]Dependent Variable: GDPR2017; [b]Predictors: (Constant), ISOC2017, GERD2017, HRST2017, INDICADM2017, INDICIS2017.

Table 9. Seasonal sustainability function for 2018

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
2018	0.912[a]	0.833	0.815	20.61332	0.833	47.747	5	48	0.000	1.666

Note: [a]Predictors: (Constant), ISOC2018, GERD2018, HRST2018, INDICADM2018, INDICIS2018; [b]Dependent Variable: GDPR2018.

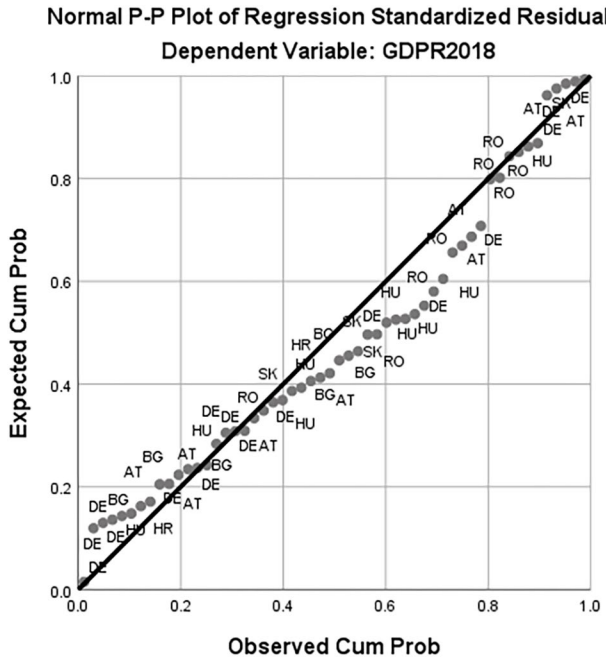

Figure 7. P-P Plot for sustainable development of EUSDR in 2018

Table 10. ANOVA test of the model for 2018

Mode		Sum of Squares	df	Mean Square	F	Sig.
2018	Regression	101441.068	5	20288.214	47.747	0.000[b]
	Residual	20395.634	48	424.909		
	Total	121836.702	53			

Note: [a]Dependent Variable: GDPR2018; [b]Predictors: (Constant), ISOC2018, GERD2018, HRST2018, INDICADM2018, INDICIS2018.

The regional sustainability component in 2019 (S_{2019r}) in relation to the digital economic development regressors generated a high level of statistical significance of 80% for a coefficient of determination R^2 = 81.7% (decreasing from 2018) and a standard error of the estimator of 21% (increasing from 2018). Compared to the distribution averages of economic development, it represents about 30% of the general level of evolution on average of digitization indicators whose dynamics at 2019 level is between 40.2–81.2% compared to the general averages of evolution calculated at EU level (see Table 11).

For the EUSDR macro-region, this means an improvement in the performance of the digital economy translated into the sustainable economy, especially in the case of internet use by individuals, in their relationship with public administration and in e-commerce, which reaches a historical high of 50.5% compared to the beginning of the analysis period. On the other hand, there has been a successive decline in the contribution of R&D to sustainable development and in the labour factor attracted to this area (see Figure 8).

Table 11. Seasonal sustainability function for 2019

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
2019	0.904[a]	0.817	0.798	21.01185	0.817	42.762	5	48	0.000	1.595

Note: [a]Predictors: (Constant), ISOC2019, GERD2019, HRST2019, INDICADM2019, INDICIS2019; [b]Dependent Variable: GDPR2019.

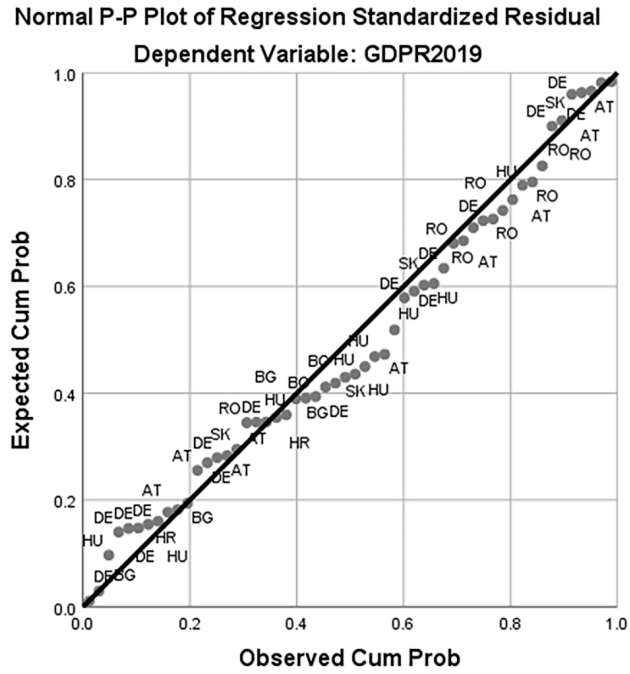

Figure 8. P-P Plot for sustainable development of EUSDR in 2019

According to Figure 8, the trend line is affected by inhomogeneities of the y*–y distribution.

From the ANOVA plot point of view, we find that the regression function is homogeneous and valid. The level of representation of the residual component in the sum of the regression squares is 18.3% and the level of representation of the degrees of freedom of the regression components is 5 out of 53 possible. The F-test has a value of 42.8 points and the Sig coefficient tends to 0 (see Table 12).

The regional sustainability component in 2020 (S_{2020r}) in relation to the digital economic development regressors generated a high level of statistical significance of 80% for a coefficient of determination R^2 = 81.5% (decreasing compared to 2019) and a standard error of the estimator of 21.4% (increasing compared to 2019). Relative to the average distribution of the economic development, it represents about 30% of the overall average level of development

of digitisation indicators, whose dynamics in 2020 are between 40.7–83.6% of the overall averages of development calculated at EU level, but under the impact of the pandemic, the distribution of the hierarchy of the components of the digital economy is modified in favour of e-commerce and the use of the internet for knowledge acquisition (including education), (see Table 13).

For the EUSDR macro-region, this means an improvement in the performance of the digital economy translated into the sustainable economy, especially in the case of internet use by individuals, in their relationship with public administration and in e-commerce, which reaches a historical high of 55.9% compared to the beginning of the analysis period. There has been a successive decline in R&D contribution to 79.1% (historical minimum), (see Figure 9).

According to Figure 9, the trend line is affected by inhomogeneities of the y*–y distribution.

From the ANOVA plot point of view, we find that the regression function is homogeneous and valid. The level of representation of the residual component in the sum of the regression squares is 18.5%, the level of representation of the degrees of freedom of the regression components is 5 out of 53 possible, the F-test is 42.3 points and the Sig coefficient tends to 0 (see Table 14).

The results of the model confirm that the regional development has a seasonal character and is influenced by digitization to a significant extent, making the combined study of the two concepts and the analysis of vulnerabilities that could trigger sustainability transformations in a pragmatic as well as conceptual way not only by referring to the macro-region delimited by EUSDR of interest. Digitization is proving to be a constant preoccupation of new researches (B. Asheim et al., 2017; Barzotto et al., 2019; Bednárová et al., 2018; Gabor et al., 2021; Gänzle & Mirtl, 2019), their approaches, however, are not as complex as the one we propose.

Table 12. ANOVA test of the model for 2019

Model		Sum of Squares	df	Mean Square	F	Sig.
2019	Regression	94397.329	5	18879.466	42.762	0.000[b]
	Residual	21191.897	48	441.498		
	Total	115589.227	53			

Note: [a]Dependent Variable: GDPR2019; [b]Predictors: (Constant), ISOC2019, GERD2019, HRST2019, INDICADM2019, INDICIS2019.

Table 13. Seasonal sustainability function for 2020

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
2020	0.903[a]	0.815	0.796	21.44489	0.815	42.264	5	48	0.000	1.605

Note: [a]Predictors: (Constant), ISOC2020, GERD2020, HRST2020, INDICADM2020, INDICIS2020; [b]Dependent Variable: GDPR2020.

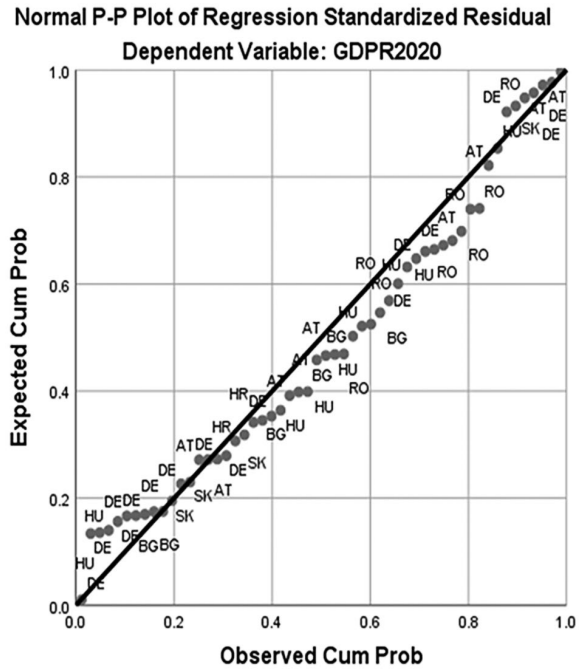

Figure 9. P-P Plot for sustainable development of the EUSDR in 2020

Table 14. ANOVA test for the model in 2020

Model		Sum of Squares	df	Mean Square	F	Sig.
2020	Regression	97182.736	5	19436.547	42.264	0.000[b]
	Residual	22074.401	48	459.883		
	Total	119257.137	53			

Note: [a]Dependent Variable: GDPR2020; [b]Predictors: (Constant), ISOC2020, GERD2020, HRST2020, INDICADM2020, INDICIS2020.

In relation to the purpose of the research, we have demonstrated that there is the possibility of configuring seasonal sustainability at least through a valid, multi-criteria model pivoting on the digital component of the economy.

4. Discussion with interpretation of results obtained

As a result of the implementation of the model, partial projections of the regional sustainability in relation to the R&D phenomenon were generated, finding that, from the regional development strategy on the R&D component point of view, the maximum point of sustainable development, marked by the homogeneity of the regression distribution cloud, is reached during 2017–2018. This period was marked by the maturing of the Strategic Partnership Treaty (EUSDR) and the ERDF (European Regional Development Plan) funding programme.

These viable opportunities have contributed to boosting R&D and have materialised in the partnership agreement through TEN-T (Trans-European Network Transport) projects for the port structure, intra-regional administrative partnership projects with the takeover of management functions by rotation and smart waste management in the Danube region.

In the context of the intensification of digitization efforts, represented by R&D expenditures, there is an improvement in the regional sustainable development, predominantly towards the end of the analyzed period, with the concentration of the distribution number of the dependent variable in relation to the regression variable (GERD), which proves hypothesis *H1*: Sustainable regional development is enhanced if and only if the investment effort represented by Intramural R&D expenditure is intensified and homogenised across the entire Danube macro-region.

As far as the implementation of R&D projects is concerned, it is necessary to analyse the human support represented by the skilled/specialist labour factor, which in turn is a component of the development of the digital economy. Without a dedicated skilled workforce, sustainable economic development would be slowed down. The sequential/seasonal analysis of the indicator reflects the fact that the peak of homogeneity in attracting specialists was represented by the period 2016–2018, a period that coincides with the funding cycles and demonstrates that to benefit from the input of skilled labour requires improved resource allocation management, given that private entities (SMEs) are reluctant/unwilling to implement R&D or to maintain a costly skilled workforce.

The sustainable regional development can only be achieved in today's context, dominated by pandemic constraints and the reconfiguration of the digital economy, with the help of science & technology professionals. Increasing the share of these professional categories in the total mass of specialists employed in the macro-regional economy is likely to sustain development and create a homogeneous, balanced macro-region in which equal opportunities and the promotion of inter-regional cooperation are optimally represented. This can be seen from the seasonal plot of the variation of the dependent variable against the HRST regressor, which tends to focus towards the origin of the axis towards the end of the period, with the reduction of regional disparities and the strengthening of the sustainable macro-regional economy. From the graph, it appears that at the level of 2020, the last two ranked in the regional competitiveness top (Slovakia and Romania) represent the only major disparities from the concentration cloud of the graph (Bednárová et al., 2018; Gabor et al., 2021). These developments prove the *H2* hypothesis: Increasing the share of the skilled labour in science & technology on the basis of a viable funded strategy can be a risk prevention factor in case of major events in order to prevent macro-regional structural imbalances and enable further sustainable development.

From the indicator on internet use by individuals' point of view, there is an increase in the phenomenon of digitization towards the end of the analyzed period, which coincides with the activation of the digital economy as an alternative to the lock-down measures adopted by the authorities in 2020. On the regional component, we observe a seasonal centering of the distribution averages towards the end of the period (2019–2020), a period that marks the alignment of distributions for developed countries and most developing countries, with the exception of Romania, which maintains a trend of extrapolation of the distribution towards

the point cloud. This is due to the strong discrepancies between urban and rural development in Romania, which caused many deficiencies in the organisation of online education and the economy during the lock-down period. As a result, regional unemployment was higher than the EU and EUSDR average.

From the analysis of the seasonal partial regression plots of the dependent variable against INDICIS, it can be seen that under conditions of uncertainty (years 2019–2020) the distribution of the point cloud is wider, which shows that the influence of the indicator on the regional variation is smaller. We note that the most sensitive vulnerability point that remains sensitive throughout the observed period is for Romania. This confirms the approach of (Gabor et al., 2021) and validates the working hypothesis *H3*: Internet use for personal purposes is an indicator with a lower contribution to sustainable development, being vulnerable to the onset of the crisis and generating disparities in sustainable development in relation to the EU's digital policy objectives.

As a result of the entry into the crisis period, the relations between individuals and public administration have acquired a pronounced dynamic character, based on the digital component. Unlike the other indicators, in this case, the distribution by clusters attributed to the level of development of public administrations stands out. This demonstrates the volatility of administrative autonomy under the conditions of digitisation, which is mainly attributed to the digital infrastructure of local and regional administrations and the willingness of the citizens to access the infrastructure. If, in terms of Internet use, we cannot speak of clusters but of an entropy assimilated to countries with a better or lesser capacity for digitisation, in terms of digital administrative capacity, this is closely linked to the level of development of countries.

The indicator on digitisation of public administration services reflects the fact that, under the impact of the new EUSDR pact and the region covered by it, there is a unified approach to the development of GDPR in relation to the digitisation of public administration at the beginning of the period under review. The differences in approach have materialised over time in the construction of two different clusters. The first targets regions from Germany and Romania, countries that achieve average performance in the digitisation of administration, while the other countries benefit from an increased input of digitisation, which additionally helps them in trying to develop a sustainable regional economy faster. This validates hypothesis *H4*: Digitization of the public administration and its connection with the citizens is an asset of smart development, under the conditions of changing the mentality of approaching the system (an aspect that has become urgent during the crisis).

As far as e-commerce is concerned, the regional evolution has been very favourable, taking into account also the crisis context, which has pushed and boosted e-commerce, resulting in an indicator that fully contributes to the regional sustainability, managing to attract around the development poles also the emerging EUSDR beneficiary countries.

Online consumption of goods and services as an indicator of sustainable economic growth in relation to the macro-region delimited by EUSDR has shown a consolidation trend in line with the development of digitalisation. In 2020, under the impact of the pandemic, the dispersion of the results can be observed, reflecting the versatile nature of the indicator which is sensitive to internal factors and external influences such as changes in the balance of trade

forces during the crisis, social protection measures and differentiated lock-down policies. Thus, hypothesis *H5* was validated: Sustainable development depends on stimulating the digital economy in a manner of Information Security and regulatory balance that prevents vulnerabilities related to the volatility function of the digital economy.

The general picture of the regional sustainability through the lens of digitization is shown in Figure 10, which contains the evolution of the Pearson correlation coefficients of the regressors with the dependent variable. It is observed that most of the indicators evaluated by modelling have a correlation of more than 70% in dynamics with the dependent variable, which means that they contribute directly to the sustainable economy growth with about 140% average input to achieve a net unit of sustainable economic growth.

The evolution charts are presented and explained according to the observations in the results chapter. There is a reduction in the dynamics of the Pearson correlation level of R&D due to the limitation of the European funding of projects in the period 2014–2020 and the transition to the new funding scheme. This has contributed to a reduction in the Pearson correlation level of the skilled labour attraction, with the end of the period (2019–2020) also reflecting the influence of the pandemic that has disrupted regional economic processes due to bottlenecks and health security measures adopted by the authorities.

As a result of this study, some directions for action emerged as follows:

- strengthening the contribution of R&D to the development of regional projects will create the conditions for greater regional sustainability and will help to identify new opportunities that will reactivate EUSDR projects;
- attracting teams of specialists to evaluate/monitor/implement these regional projects is an urgent necessity especially in the current context of the crisis, a context marked by the reduction of the traditional commercial market and the redundancy of a large number of specialists through the closure of SMEs;

GDPR	2014	2015	2016	2017	2018	2019	2020
GERD	0.808	0.818	0.811	0.818	0.808	0.794	0.795
HRST	0.852	0.850	0.853	0.855	0.842	0.837	0.833
INDICIS	0.741	0.753	0.721	0.771	0.793	0.712	0.702
INDICADM	0.696	0.738	0.670	0.639	0.623	0.623	0.645
ISOC	0.741	0.732	0.706	0.707	0.708	0.641	0.676

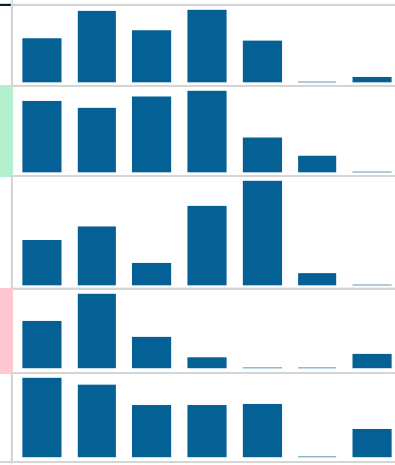

Figure 10. Pearson correlation overview with seasonal influence and impact on sustainable regional development

- the environmental issue is a component of the sustainable development that requires joint projects considering the Danube route. These projects can be carried out in a more efficient way within the framework of digital public administrations. In a broader sense, the digital administrations can directly contribute to the sustainable regional development, one example being smart cities. In the EUSDR countries, most smart cities are found in Austria and Germany, and the fewest in Romania;
- boosting e-commerce by creating partnerships between regional manufacturers with digital commerce distribution is an alternative to the current economic bottlenecks caused by the crisis.

Conclusions

The authors initiated this approach to highlight the changing economic structure and the trends of the digitalization amplification through the prism of a dynamic multi-criteria model, assessing the strategic perspective by pivoting digitalization in the strategic equation. This desideratum was supported by a structured analysis in which the literature review showed that although there is a real and consistent concern for regional development in the digital economy, yet the pragmatism of the research often omits significant details, these being frequently oriented towards situational identification of regional economic status with theoretical orientations towards integration and remedying structural dysfunctions.

The followed objectives during the research showed that the economic status can be dynamically adjusted based on the monitoring of regional economic indicators through corrective policies that the authorities have to link with the supra-regional dimension, i.e. EU policies and global strategies. The design of the dynamic model and its validation is an important point of our approach which confirms the above. In the Discussions section, the authors have formulated valuable proposals based on the observations that can be easily implemented by EUSDR regional decision makers.

This study carried out by the authors started from the premise of evaluating the opportunities of the macro-regional association in the context of current phenomena such as digitalisation and global crisis. The authors conducted a critical study based on data reported by Eurostat, which demonstrated the influence of both digitisation and pandemics on the regional sustainable growth (see Figure 8).

The present study has a pronounced novel and practical character. It provides viable solutions for relaunching the EUSDR partnership and creating new directions for action on this treaty. In the current geo-political context, the study offers a new perspective on the development of the macro-region in order to find viable solutions at international level related to the energy, food, health crises, etc. The analysis takes into account the new opportunitiesnew and threats in the Danube region in this context and offers new solutions (pre- and pandemic digitisation). Moreover, our proposed model stands out by combining economic, social and R&D indicators, which allow a better substantiation of the proposed solutions to mitigate regional disparities at the EUSDR level.

The limitations of the study are the number of indicators of the digital economy that were analysed and the period for which we identified data. This does not mean that new indicators

cannot be added to our proposed model. For a better comprehensiveness, demographic indicators, sustainable development indicators on the 17 objectives proposed in the Sustainable Development Strategy at European level can and will be added to the future research.

We appreciate that pandemic developments have favoured the large-scale implementation of digitisation with a major impact on all sustainable development objectives, favouring e-commerce and the development of digital jobs, which have a long-term impact on reducing poverty rates through better management of trade flows and easier coverage of risk areas.

At the same time, digitisation favours access to knowledge, as the quality of education can be improved through online education programmes, including on healthy lifestyles (impact on Sustainable Development Strategy goals 3 and 4). In the online environment gender equality can be easily promoted, and the digital economy can be a sustainable alternative for environmental protection, providing resources for reducing inequality and promoting alternative employment with disabilities from home (goals 6 and 10 of the Sustainable Development Strategy).

The authors plan to extend this research at a future stage. The future research directions concern: the identification of possibilities for regional development in the current geopolitical context, the study of the dependence of regional development on EU funding programmes, the study of possible strategies to be implemented to increase social cohesion in the EUSDR in the uncertain geopolitical context and the study of effective possibilities to reduce regional disparities in the EUSDR.

Conflicts of interests

The authors declare that there are no conflicts of interest.

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