Assessing digital divide in European transition economies: The application of multidimensional scaling to ICT-related data

DORKA VIRÁG NEMÉNY – BALÁZS ISTVÁN TÓTH*

As digitalisation has become increasingly crucial for economic growth, competitiveness and sustainable development, digital development and digital transformation have been of concern in the European Union for the last decades. The study aims to analyse the digital divide and classify the NUTS-2 regions of Central and South-East European transition economies according to similar digitalisation levels between 2016 and 2021. After setting out the necessary terminological background on digital divide and providing an overview on the key areas of action to promote digital development and transition in the EU, a database of seven ICT-related indicators from Eurostat was compiled for 49 regions and multidimensional scaling was applied for exploring the similarities and differences between them. An important conclusion is that there is still a sharp divide among the regions of the European transition economies. It is also found that regions belonging to the same country are more similar than different, and digitalisation characteristics have not changed

* *Dorka Virág Nemény* is Research Assistant at the University of Sopron, Alexandre Lamfalussy Faculty of Economics. E-mail: nemeny.dorka@uni-sopron.hu, ORCID: https://orcid.org/0009-0006-4299-8827

Balázs István Tóth PhD habil. is Associate Professor at the University of Sopron, Alexandre Lamfalussy Faculty of Economics. E-mail: toth.balazs.istvan@uni-sopron.hu ORCID: https://orcid.org/0000-0002-9549-313X

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in relative terms. The study may contribute to the deeper understanding, ongoing discussion, and fruitful debate of the situation of digitalisation on both European and sub-national levels.

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Introduction

There is no doubt that digitalisation and information and communication technologies (ICT) have become crucial in driving economic growth (Vu et al., 2020), improving the competitiveness of the economy (Boikova et al., 2021) and creating sustainable development (Mondejar et al., 2021) for the last decades. Humanity has moved into an emerging 'virtual world' of socio-economic development in which online infrastructure, virtual trade and online markets grow in importance (Øverby & Audestad, 2021). On the one hand, digitalisation is an opportunity to reduce costs, provide new services, establish new business models and technologies, and break out of poverty. On the other hand, the access, use and benefit of ICT are disproportionate (Nevado-Peña et al., 2019), and many are benefiting much less and fall behind; thus, it is no surprise that there is also a sorting out in every society.

The adoption of telecommunication and the use of ICT opened broad avenues also for regional development by giving local production systems greater competitiveness and efficiency (Capello & Nijkamp, 1996; Yilmaz & Dinc, 2002; Capello, 2016). However, new threats arise as technologies advance; for instance, the issue of digital divide emerges in every society, whereby some people and some places – especially geographical space without technology – are being 'left out' of the new information economy, resulting in increasing development gaps between regions (Stimson et al., 2006). Besides, a quick spread of the crisis triggered by the COVID-19 pandemic and its consequences accelerated digital transformation (Agostino et al., 2021); this has become particularly important when national governments have implemented extraordinary measures, such as lockdowns or social distancing, which have contributed to the application of ITCs (Ha, 2022).

Geographic digital divide situations are occurring in many parts of the world including in the European Union (Várallyai et al., 2015; Szeles & Simionescu, 2020; Boikova et al., 2021; Elena-Bucea et al., 2021; Reveiu et al., 2022). ICTs are critical in improving the competitiveness of European industry and meeting the demands of the society and the economy. Therefore, avoiding the deepening of the digital divide and facilitating digital transformation have been of high priority in the European single market. Accordingly, the European Council and the European Commission set out priority areas in strategic agendas (Lisbon Strategy, Europe 2020 Strategy, A new strategic agenda for the EU 2019–2024) as well as political guidelines and initiatives (Commission priorities for 2019–2024, Digital Agenda, Digital Compass) to encourage the shift to a knowledge-based society through the use of the key elements of modern economies, such as the Internet, e-business, e-commerce, research and development, telecommunication, e-inclusion etc. (European Commission, 2010a; 2010b; 2020a; 2021).

In the EU, to satisfy local needs (Reggi & Gil-Garcia, 2021), digitalisation as a process of applying digital technologies and infrastructures in diverse dimensions of businesses, households and individuals has come into focus for the last two decades (Pinto et al., 2023). Accordingly, it is important to examine the smallest units of society to get better insight into digitalisation levels. It is also crucial to know more about the characteristics of digital divide in the EU Member States that joined the EU after the millennium to understand whether the regional digital gap has grown or narrowed within and among these countries. This group of European countries are often termed as 'transition economies' as they discovered the power of market economy in the late 1980s and early 1990s after the collapse of command economies and centrally planned (bureaucratically controlled) systems.

The main objective of this work is to empirically analyse the characteristics of digital divide on regional (NUTS-2[1]) level in European transition economies through measuring the recent changes (2016–2021[2]) in the use of ICT. The specific research questions of the study are as follows: What is 'digital divide' and what factors influence it? How can it be assessed and measured on regional (NUTS-2) level? What is the role of the EU in promoting digital development? What are the related objectives and fields of action? How does the EU financially support digitalisation? Does 'digital divide' exist in the Central and South-East European transition economies and

[1] The acronym of NUTS stands for Nomenclature of Territorial Units for Statistics. It is a geocode standard for referencing the subdivisions of countries for statistical purposes. It was set up as a single and coherent system for dividing up the EU's territory to elaborate regional statistics.

[2] According to the fifth amendment to the NUTS classification, which became effective in December 2016 and has been applied since January 2018, the 2013 NUTS version was replaced by the 2016 one. This caused boundary changes in administrative areas on the NUTS-2 level (European Commission, 2016). Accordingly, the performance of NUTS-2 regions can be compared from 2016 on.

in their regions? If yes, how can regions be classified, which clusters have regions fallen into over the years, and what are the common characteristics of the regions belonging to the same category?

In this report, the term 'transition economies' covers 11 Central and South-East European countries (CSE-11), which joined the EU in the 2000s. In other words, CSE-11 includes countries that are Member States of the EU since 2004, namely Bulgaria (BG), Croatia (HR), Czechia (Czech Republic) (CZ), Estonia (EE), Hungary (HU), Latvia (LV), Lithuania (LT), Poland (PL), Romania (RO), Slovakia (SK) and Slovenia (SI).[3]

The research methods applied in this paper comprise, on the one hand, literature review of the terminological background and the dimensions of digital divide, textual analysis for mapping the content of existing policy documents, actions and initiatives and identification of the financial background shaping the EU's digital future. On the other hand, a form of multivariate analysis, multidimensional scaling is used as explanatory tool and assessment technique to measure ICT use empirically on NUTS-2 regional level in CSE-11 countries. The dataset considers the following three years: 2016 (baseline year), 2019 (last year of economic boom before the outbreak of the COVID-19 pandemic) and 2021 (data for the last available year). The empirical analysis is based on secondary data collection from the openly available database of Eurostat. Regional breakdowns are derived from a selection of indicators disseminated in the regional tables (Regional statistics by NUTS classification / Regional digital economy and society). In this study, seven indicators from regional ICT statistics were selected to measure ICT use by households and individuals.[4]

This report is organised as follows. The first part contains the review of the relevant literature and the second one highlights the database and the applied methods. The third part covers the results and the fifths one constitutes the summary and conclusions with highlighting the limitations and the future research directions.

[3] International Monetary Fund (2000) and World Bank (2002) classify several other countries as "transition economies", such as countries in the former Soviet Union (Commonwealth of Independent States), in Asia (e.g. Cambodia, Vietnam), as well as non-EU countries in Europe (e.g. Albania, Bosnia and Herzegovina, Northern Macedonia). However, these countries are not considered in this paper.

[4] Due to lack of data in the regional tables, firm-level figures were not considered in this paper. Regional statistics offer data relating to the units of households and individuals.

Literature review

Digital divide: terminological background and dimensions

According to the standard definition proposed by the OECD (2001), digital divide refers to the gap between individuals, households, businesses, as well as geographic areas at different socio-economic levels with regard both to their opportunities to access ICT and the use of the Internet for a wide variety of activities. Accordingly, digital divide emerges both between and within countries, and the differences between opportunities for connectedness and availability of ICT for people derive from several diverse sources and reasons.

A very simple explanation by Norris (2001) is as follows: digital divide is any and every disparity within the online community. As research on the subject evolved and new aspects of digitalisation emerged, interpretations were revised. For instance, Fuchs & Horak (2007:15–16) gave a complex explanation of digital divide: it refers to "unequal patterns of material access, usage capabilities, benefits, and participation concerning ICT" that are "due to the asymmetric distribution of economic (money, property), political (power, social relationships), and cultural capital (skills)". As Bruno et al. (2011) pointed out, the debate on *the definition of digital divide* among practitioners and scholars from different academic circles is constant whereas *the concept of digital divide* is dynamic and evolving, shifting from focusing solely on access to technological resources to a multidimensional understanding of inequality and includes a complex set of divides caused by a variety of factors.

Widespread research in academic circles and policy discussions occurred about the growing importance of the digital divide. Of the firsts, Riggins & Dewan (2005) systematised the different approaches towards digital divide and concluded that the research topic was of high importance.

Norris (2001) underlined the multidimensionality of digital divide and distinguished three dimensions of digital divide. *Global divide* among countries refers to the dichotomy of integration into the digital world between developed and developing countries, *social stratification* within countries reflects the differences between technological resource availability of certain social groups within a country, and *democratic divide* concerns the difference between people who use and do not use digital networks for civic and public engagement.

Wei et al. (2011) also revealed the levels of digital divide; according to their classification, digital divide can be captured on three levels:

- *Individual level:* the gap is originally between individuals. Certain people and groups of people are technologically, sociologically or economically disadvantaged; therefore, they lack access to ICT.
- *Organisational level:* on the one hand, some organisations can utilise ICT for gaining advantage against rivals or changing the circumstances within their industry; on the other hand, there are several other organisations that lag behind technologically and are strategically disadvantaged.
- *Global level:* there are significant differences between countries. Some countries have already succeeded in promoting digital development and competence, while others still struggle with providing rural areas with broadband access. This phenomenon can be observed not only on country level, but on regional level as well.

According to Lucendo-Monedero et al. (2019), the initial understanding of the digital divide was solely restricted to the conditions available in a particular territory, namely the ability to access information (known as the first-level digital divide, also referred to as the access divide or narrow sense of digital divide). According to Scheerder et al. (2017), the common practice is to capture the availability or unavailability of ICT as the basis of measuring digital divide. The authors emphasised that in several advanced countries, the first level of digital divide has lost its fundamental role in creating inequalities as broadband access and the availability of digital devices has become prevalent.

The next step in understanding digital divide is to consider the different motives in ICT usage. This level is frequently referred to as second-level digital divide or capability divide. Moreover, the accumulation of digital competencies can be termed as 'digital capital' (Ragnedda, 2018). These competencies consist of information, communication, safety, content creation, problem-solving and the usage of digital technology. From this viewpoint, digital competencies refer to a set of internalized ability and aptitude.[5]

As research on the subject evolved, another crucial factor emerged to describe the differences between individuals and households in connection with ICT use, namely the benefits from ICT usage. For example, van Deursen et al. (2014) examined the importance of certain sets of skills (communication, operational, formal,

[5] The possession of digital capital affects both the second and the third level of digital divide. Besides, the higher level of Internet use proficiency enables to convert digital capital to other forms of capital, such as economic, social, and relational capital (Ragnedda, 2018). Furthermore, according to Park (2017), digital capital can be understood as an integral digital ecosystem that is formed on the basis on human interaction during which digital technologies are used as platform.

information and strategic ones) that influence the individual benefits of Internet use. This stage of digital divide can be referred to as the third level of digital divide or outcome divide.

As Vicente & López (2011) noticed, previous research on the subject had focused on two relevant issues: the *measurement* of digital divide regarding its extent, evolution and pace, and the explanation of digital divide through the assessment of its *drivers*. The authors revealed that ICT adoption is determined by several factors, such as the wealth of territories and individuals (e.g., income level that affects the infrastructure and diffusion of ICT technologies), socio-demographic factors (e.g., level of education and urbanization, population density, age of the population, racial construction), institutional and governmental factors, commercial openness, and cultural elements. Besides, network effects (spillover) play a crucial role as the extent of ICT diffusion of the surrounding environment influences the likelihood of acquiring such technologies.

Capello (2016) stressed that the effects of ICT on regional disparities is still dubious. In the past 15 to 20 years, two currents of thought have interpreted the impact of ICT on regional disparities. According to the first viewpoint, new ICTs can resolve the problem of peripherality. The greater access to information, knowledge and specific services to production reduce the disadvantages of a peripheral location. The second opinion argues that stronger areas of great potential demand and of more knowledge can better exploit technologies, so the gap widens between the core and the periphery.

The explanation of digital divide on regional basis have recently been put in the spotlight as fresh reports in the field show. For instance, Nevado-Peña et al. (2019) suggested that the relationship between the quality of life of citizens and the technological characteristic of areas is clearly detectable as the most technologically developed societies are happier in general. However, the elimination of the gap between regions is a challenging task and can only be successful when paired with the promotion of research and development (R&D) and investment in the training of people.

According to Mondejar et al. (2021), advanced digital technologies – such as Internet of things (IoT), big data management and artificial intelligence (AI) – are perfect means to enhance sustainable development. The contribution of these technologies to the development of agriculture, smart cities, water accessibility, energy efficiency, green manufacturing, healthcare, as well as to the fight against climate change is undeniable; however, without ensuring equal access to data, the process of digitalisation can lead to the further increase of digital divide instead of closing the gap.

Furthermore, Øverby & Audestad (2021) noticed that although there has been an increase in the access to Internet worldwide over the last decade, the key issue to tackle is to provide the developing areas with access to the Internet as there are still significant differences – an existing digital divide – within and between countries.

Bannykh & Kostina (2022) pointed out that according to the claims of modern researchers, there are already four levels of the digital divide due to the ongoing digital changes: geographic, technological, cultural, and spiritual. The authors underline the increased vulnerability of certain social groups, such as elderly people and residents of small settlements in peripheral areas. For instance, Szeles (2021) underlined that digital divide represents a significant factor of social exclusion and marginalisation, and concluded that this relationship is a bi-causal one, meaning that the inequality of opportunity to access and use digital technologies can be regarded as a result of exclusion and marginalisation, and the digital divide is a factor of exclusion as the lack of access to ICT restrains the users' ability to upgrade their social status.

In addition, there has been a change in narrative with user-experience, engagement and co-creation taking place in service design and technology as COVID-19 has affected all areas of public service delivery, with public authorities having to move their operations wholly or in partly online. Both governments and organisations had to act and react over a short period (Agostino et al., 2021). Without doubt, the COVID-19-induced digital acceleration is an opportunity to follow how digital gaps changed in the last couple of years.

Digital transformation: the issue of digital development in the EU

The institutions of the EU consider ICT to be critical for improving the competitiveness of European industry in meeting the demands of its society and economy, as they are essential for developing knowledge-intensive products and services. Also, ICT-related skills (e-skills) issues have grown in importance to ensure that every citizen is digital literate in a lifelong learning context (e-inclusion). Moreover, key enabling technologies are crucial for reaching a low carbon economy.

To efficiently promote digital transformation and counteract against existing digital divide, which is characteristic in the EU according to recent studies (Várallyai et al., 2015; Boikova et al., 2021; Szeles et al., 2020; Reggi & Gil-Garcia, 2021; Szeles, 2021; Lamberti et al., 2023), it is crucial to identify the way the EU influences digitalisation. One of the first initiatives was ‘i2010’ that promoted the positive contribution of ICT to the economy, society, and the quality of life (Commission of the European Communities, 2005). Further policy actions have been taken over the 2010s and at the beginning of the 2020s.

The Digital Agenda for Europe (European Commission, 2010a) was launched by the European Commission as a flagship initiative of the Europe 2020 Strategy (European Commission, 2010b). The Agenda was created to identify the key enabling role of ICT that is essential for reaching the priorities of the Europe 2020 Strategy. The Agenda aimed at creating adequate circumstances and preparing the single market to the challenges of the following decades (spurring innovation, economic growth, and improvement in the daily lives of citizens and businesses) from which fields, such as healthcare, public transportation, the environment etc. benefit. The Agenda highlighted the importance of the ICT sector to the economy and society as well as its enabling role to other sectors by comparing its impact to the one of development of electricity and transportation networks previously. Seven obstacles (e.g., lack of digital literacy and skills, missed opportunities in addressing societal challenges) were identified that prevent the EU from breaking out of its lagging position in the global competition caused by the incompleteness of the single market to the online world.

For combatting such challenges, the virtuous cycle of the digital economy, which is formed around three interdependent pillars (creation of content and borderless services, increase of service demand and roll-out of networks) is proposed in the document. The Agenda is formed around seven action areas that are translated further into sixteen key actions. For reaching the objectives, continuous engagement and commitment were required on the regional, the national and the EU level.

In 2019, the European Council set four priority areas that shape the political and policy agenda until 2024[6]. One of the priorities (developing a strong and vibrant economic base) aims to build a resilient economy by embracing digital transformation. Besides, the von der Leyen European Commission determined six political priorities derived from the European Council’s strategic agenda and discussions with the political groups of the European Parliament. One of the Commission’s priorities, ‘A Europe fit for the digital age’, aims to embrace digital transformation by investing in businesses, research and innovation, reforming data protection, empowering people with the skills necessary for a new generation of technologies and designing rules to match.

[6] European Union priorities 2019–2024. Available at https://european-union.europa.eu/priorities-and-actions/eu-priorities/european-union-priorities-2019-2024_en

The EU's digital strategy was formed with the purpose of facilitating the digital transformation of people and businesses, while at the same time supporting the climate neutral Europe by 2050. In addition, Europe aims to strengthen its digital sovereignty and set the standards instead of accepting them. The most relevant issues considering this topic are digital skills and jobs, connectivity and digital identity for all Europeans.

The European Commission formulated its vision for shaping Europe's digital future (European Commission, 2020a). With this document, the Commission EC set out three key objectives (technology that works for people, a fair and competitive economy, and an open, democratic, and sustainable society) that can lead Europe through the digital transformation while benefiting people and respecting values and helping the EU become a trendsetter. In March 2021, the 2030 Digital Compass (European Commission, 2021) was released to lead Europe through the digital transformation. The Compass revolves around four cardinal points (skill, infrastructure, business and government) and defines more than dozen quantitative targets.

The Digital Economy and Society Index (DESI)[7] developed by the European Commission is an assessment system created with the aim to comparatively monitor the digital progress and digitalisation levels of EU Member States. The multidimensional index is used for analysing the digital transformation of Member States, industrial sectors, and socio-economic dimensions of the EU. The DESI reports published on an annual basis have been released since 2014 with country profiles and thematic chapters to evaluate digitalisation levels. The key areas of DESI are as follows: 1) Human capital; 2) Connectivity; 3) Integration of digital technology; 4) Digital public services. According to Bánhidi et al. (2020), the main advantage of the DESI is its methodology since it is general and applicable. Although DESI is widely used among practitioners and policy makers, the index has certain limitations. It does not have a regional layer and does not include information that is detailed enough to make an adequate deep analysis or to explain certain phenomena related to digitalisation, the composition of dimensions changes yearly, and there are differences between the approaches used by statistical offices.

The Digital Economy and Society Index 2022 shows that Member States have made progress in general, however, the implementation of key digital technologies for businesses has remained at a low level. Thus, further efforts are needed for the full deployment of ubiquitous connectivity infrastructure and the advancement of

[7] Available at https://digital-strategy.ec.europa.eu/en/policies/desi

insufficient digital skills as these phenomena can deepen the digital divide (European Commission, 2022). The overall 2022 DESI results indicate an unsatisfactory picture for the CSE-11 countries: only Estonia, Slovenia and Latvia are above the EU average, and four out of the five worst performers belong to transition economies, namely Romania, Bulgaria, Poland, and Slovakia (plus Greece).

As digital transformation became a field of key importance for the EU with the release of the Digital Agenda for Europe, substantial financial contribution from the EU was allocated for the execution of digital transformation in the 2014–2020 Multiannual Financial Framework (MFF). Heading 1a (Smart and inclusive growth – Economic, social, and territorial cohesion) covered an amount of € 371.4 billion that is 34 per cent of the overall MFF. The initiation called Connecting Europe Facility accounts for 12 per cent of Heading 1a, and by that, it was the third largest share in this heading (European Commission, 2013).

The focus of 2021–2027 MFF has shifted in the sense that digitalisation and digital development became crucially important areas for the future of the EU. Heading 1 (Single Market, Innovation and Digital) received altogether € 143.4 billion of total allocation from MFF and Next Generation EU (NGU) (European Commission, 2020b). In addition, in the period of 2021–2027 MFF, aspects related to climate change and digitalisation are handled as high priorities in each program; besides, 20 per cent of funds from the Recovery and Resilience Facility (RRF) must be allocated for these purposes.

Data and methods

The dataset

Based on Eurostat's Regional digital economy and society database, a dataset of 7 ICT-related indicators is employed in this paper.[8] Our dataset relates to the period 2016–2021; accordingly, it partially covers the years of COVID-19 crisis. The geographical unit of the analysis is represented by the NUTS-2 regions, accord-

[8] EU survey on the use of ICT in households and by individuals is an annual survey conducted since 2002 aiming at collecting and disseminating harmonised and comparable information on the use of ICT in households and by individuals. Data presented in this domain are collected by the National Statistical Institutes and are based on Eurostat's annual model questionnaire. This questionnaire is updated each year to reflect the evolving situation of ICT. Indicators from this survey are used for benchmarking purposes. This survey supports measuring the implementation of priorities for the period 2019–2024 of the von der Leyen European Commission (ICT usage in households and by individuals. Available at https://ec.europa.eu/eurostat/cache/metadata/en/isoc_i_esms.htm).

ing to NUTS version 2016. In this report, 49 regions from CSE-11 countries are involved. All countries are Member States of the European Union and known as transition economies. Due to the lack of data, NUTS-2 level figures are substituted with numbers on corresponding NUTS-1 levels for Poland. For Hungary and Lithuania, there has been a minor change in the NUTS versions, so NUTS-2 level data are replaced with country level data for 2016 and 2017 in the following regions: Budapest (HU11), Pest (HU12), Sostines regionas (LT01) and Vidurio ir vakaru Lietuvos regionas (LT02).[9]

The selected indicators are presented in Table 1. The indicators used to assess the digital divide are grouped into the three levels of digital divide presented in the previous chapter. The first two indicators (1. Households with broadband access; 2. Frequency of Internet access: daily) reflect access to and use of ICT by individuals and in households (first level of digital divide). Four indicators (3. Internet use: participating in social networks; 4. Internet use: interaction with public authorities; 5. Internet use: Internet banking; 6. Online purchases: from sellers from other EU countries) are more concerned with ICT competence and skills (second level of digital divide). These indicators reflect the skills in using of the Internet and social networks for different purposes (e-commerce, exchange information and services with governments and public administrations, e-government). Finally, 'Internet use: selling goods or services' (indicator no. 7) serve as a good measure of the third level of the digital divide as it captures an essential action to realise economic benefit through online commerce. The abbreviations shown in the fourth column of Table 1. are used consequently in the study from this point.

Table 1.

Set of indicators

Nr.	Name of indicator	Definition of indicator	Abbreviation	Measurement unit
Indicators related to first level digital divide (digital access)				
1.	Households with broadband access	The indicator measures the share of private households with broadband access (density of broadband Internet services).	BBACC	% of households

[9] Geo-labels and geo-codes are available in Appendix 1.

Nr.	Name of indicator	Definition of indicator	Abbreviation	Measurement unit
2.	Frequency of Internet access: daily	The indicator measures the percentage of individuals who regularly use the Internet.	DUINT	% of individuals
Indicators related to second level digital divide (digital competence)				
3.	Internet use: participating in social networks	The indicator measures the use of Internet for the following purposes: creating user profile, posting messages or other contributions to Facebook, Twitter etc.	SOCMED	% of individuals
4.	Internet use: interaction with public authorities	The indicator measures the percentage of individuals who used the Internet to exchange information and services with governments and public administrations in the last 12 months.	PUBAU	% of individuals
5.	Internet use: Internet banking	The indicator measures the percentage of individuals who used online banking services.	ONBANK	% of individuals
6.	Online purchases: from sellers from other EU countries	The indicator measures the percentage of individuals who ordered goods and services online from other EU Member States.	ORDER	% of individuals
Indicator related to third level digital divide (digital outcome)				
7.	Internet use: selling goods or services	The indicator measures the percentage of individuals who sold goods and services online.	ONSELL	% of individuals

Source: Own elaboration.

The applied method

The application of multidimensional scaling (MDS) is based on data of ‘distance’ or ‘similarity’ nature, or data that can be transformed into such. MDS refers to a set of statistical techniques that are used to reduce the complexity of a data set, permitting visual appreciation of the underlying relational structures contained therein. With this method, one can systematically create geometric representations for given objects (e.g., regions), which reflect the relationship of these objects in a geometric space with the appropriate number of dimensions with the smallest possible distortion.

One can evidence that the application of the MDS method is still actual in space-specific research (Bánhidi et al., 2020; Dehnel et al., 2020; Bulut et al., 2022; Altintas, 2022). In this study, to show the similarities and differences, in other words, to capture the sense of 'distance' and 'similarity' among the NUTS-2 regions regarding their performance in the 7 ICT-related indicators, we reduce the original seven dimensions (indicators) to the two-dimensional space by performing MDS.[10] We use the IBM SPSS (Statistical Package for Social Sciences, 25th version) for conducting the analysis. Out of the two common techniques of performing this analysis, Alscal routine and Proxscal routine, the latter is chosen.[11] MDS Proxscal routine can be reached under the following command line in SPSS: Analyze/Scale/Multidimensional Scaling (PROXSCAL). In the Data Format dialog box, create proximities from data is selected as proximities among the regions are generated. Values are standardized, so none unequally high weights can be assigned to any indicator that would influence the results. Concerning the test statistics, the S-stress formula is widely used to express the goodness of fit of the MDS model (Kruskal, 1964). It is calculated as follows:

$$S - stress = \sqrt{\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}(d_{ij} - d_{ij}^{*})^2}{\sum_{i=1}^{n}\sum_{j=1}^{n}(d_{ij})^2}}$$

where (d_{ij}) is the (initial) distance matrix consisting of symmetric, non-negative elements, as well as $(d_{ij} - d_{ij}^{*})$ the distance matrix that measures the difference in numerical terms. If there is a perfect correspondence between the originally detected and the depicted differences $(d_{ij} - d_{ij}^{*})$, then the error is zero, and so is the value of the S-stress. In other words, SPSS examines and selects the configuration for which

[10] Besides the MDS method, factor analysis/principal component analysis (PCA) can be used for exploratory data analysis and pattern recognition. Geometrically, both techniques seek a lower dimensional representation of the data set. While MDS is based on distances among objects and looks for similarities between objects, PCA is based on angles among vectors and looks for similarities between features (variables). In addition, PCA is based on the general linear model and produces orthogonal principal components, whereas MDS has no such restrictive assumption and does not impose orthogonality constraints. Furthermore, MDS handles smaller data sets efficiently and may result in lower dimensional solutions enabling data visualisation on the two-dimensional plane. Lastly, as Saeed et al. (2018) pointed out, unlike factor analysis, MDS does not depend on the assumptions of linearity and normality.

[11] SPSS offers Proxscal (Proximity Scaling) as an alternative to Alscal (alternating least squares scaling). While Alscal assumes that the input is a dissimilarity matrix, Proxscal allows one to specify whether the proximities are similarity or dissimilarity measures (Leydesdorff & Vaughan, 2006).

the value of S-stress is minimal. Therefore, the smallest possible value of S-stress is desirable because it corresponds to the smallest distortion.[12]

We test five different distance methods (also known as Minkowski p-values). The goodness of fit for all the possible intervals is tested to decide which distance method is the most adequate for the dataset. In the case of the Euclidean distance (p = 2) for all examined years, and in the case of the Minkowski distance (p = 3) regarding the years 2019 and 2021, the S-Stress values seem to be 'excellent' (S-Stress values are between 0.025 and 0.049). However, out of the possible options, the best fit measures can be associated with the Manhattan distance (p = 1) as the S-Stress values fall in the 'near perfect fit' category as they are between 0.000 and 0.024. Accordingly, this distance method is used for further analysis on the subject.[13]

Results

In this section, we create scatter plots to make results more apparent. Each region is marked with a dot and labelled with geocode. On the figures, regions in the most favourable positions can be found in the upper right corner of the diagram. In contrast, regions with relatively low-level performance can be detected in the bottom left corner of the diagram. Besides, along the Dimension 1, which compresses six out of the original seven indicators, a map of regions is presented to show the classification of regions according to three categories (clusters): 'Laggards', 'Average' and 'Leaders'. While 'Laggards' consists of regions that have relatively low performance (MDS scores are below –0.50 along the first dimension), 'Leaders' includes regions with relatively high levels in ICT infrastructure and ICT usage (MDS scores are above +0.05 along the first dimension). Every other region is labelled 'Average' (MDS scores are between –0.50 and +0.50).

The visual representation of the 2016 MDS results is shown on Figure 1. Six indicators are compressed in Dimension 1; their order from top to bottom is determined by the influence ('power') on the dimension: DUINT, PUBAU, ONBANK, ORDER, BBACC and ONSELL. Dimension 2. is determined only by SOCMED.

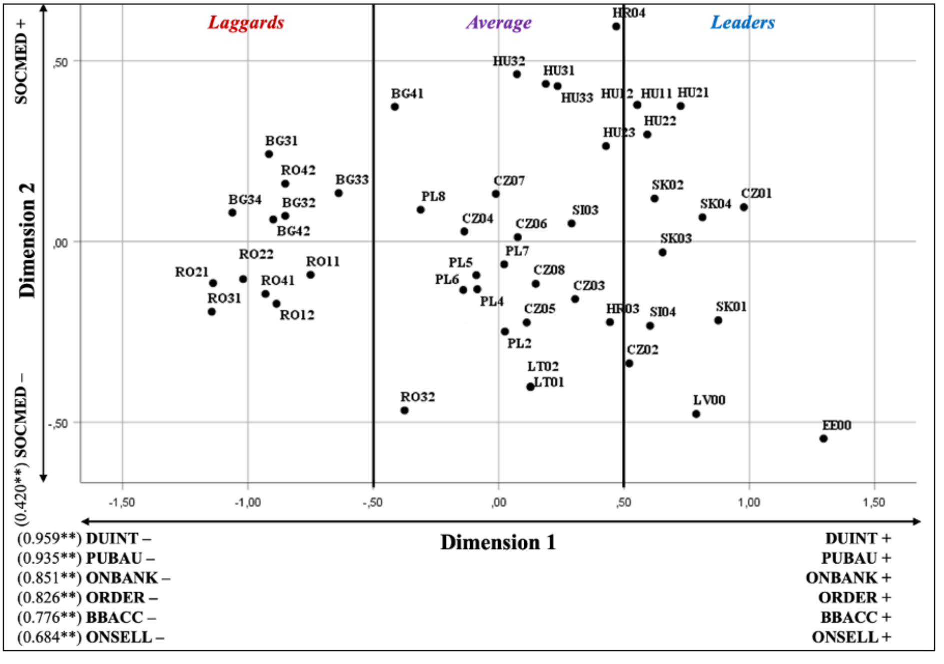
[12] S-stress value evaluation (rule of thumb): between 0.00 and 0.05: the quality of the reconstruction is excellent (probably contains all relevant information); between 0.05 and 0.10: the quality is good (results can be interpreted); between 0.01 and 0.02: the quality is acceptable (it is worth dealing with, the result is still interpretable); above 0.20: poor quality of reconstruction.

[13] MDS test statistics are presented in Appendix 2. SPSS data file (MDS.sav) and output table (MDS.spv) are available at https://github.com/nemenydorka/K-lgazdas-g-

Regarding Dimension 1, the worst results have been reported from the Romanian and Bulgarian regions, apart from the capital regions (Bucuresti-Ilfov–RO32, Yugozapaden–BG41), as they belong to the 'Average'. The three top performers are Estonia (EE00), Prague (CZ01) and Bratislava (SK01). An important finding of the study is that regions from the same country tend to group together; while Czech and Polish regions congregate in the 'Average' category, Hungarian regions cluster close together in the groups of 'Average' and 'Leaders', Slovakian regions can be found among 'Leaders', as well as regions of Bulgarian and Romanian countryside can be detected in the 'Laggards'.

Figure 1.

MDS results in CSE-11 NUTS-2 regions, 2016

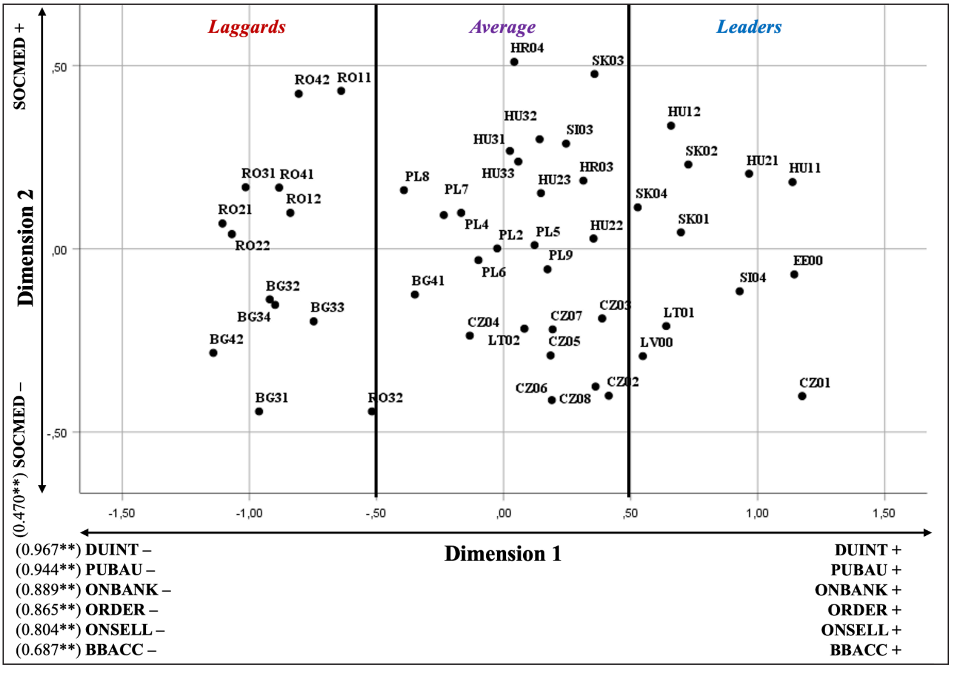


Note: ** Variable correlations at 95% confidence (p<0.050). Makroregion Województwo Mazowieckie (PL9) is not shown on this figure due to lack of data.

Source: Own elaboration.

Figure 2.

MDS results of CSE-11 NUTS-2 regions, 2019



Note: ** Variable correlations at 95% confidence (p<0.050).

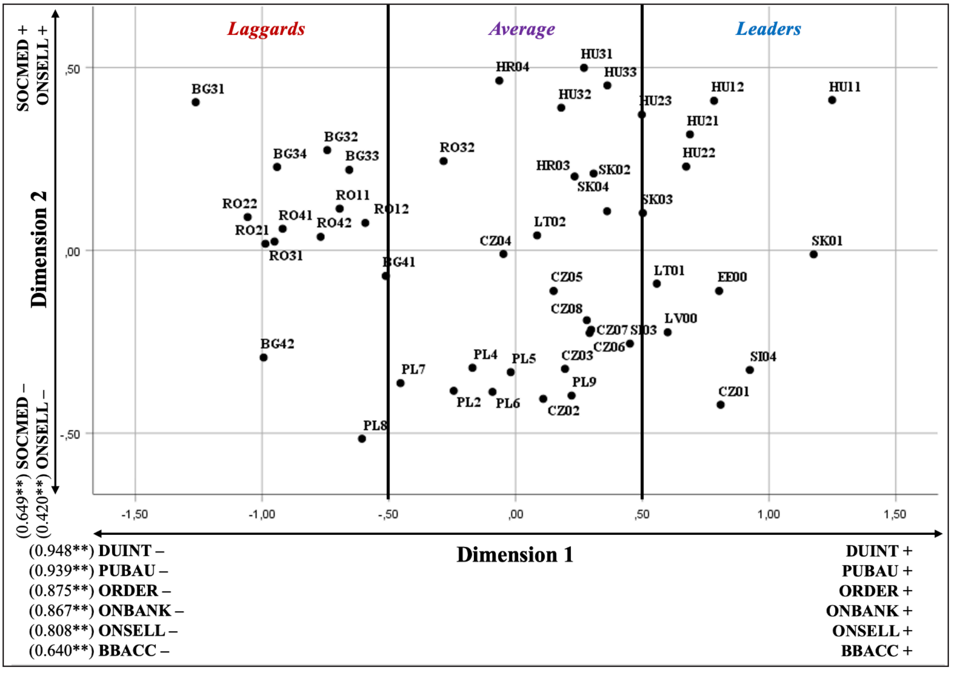
Source: Own elaboration.

MDS results for the year 2019 are shown on Figure 2. The variable and dimension correlations have not changed sharply. Similarly to the previous case, six indicators determine Dimension 1, and one indicator is compressed in Dimension 2. The results show many similarities with the results from the year 2016. For instance, the lowest performance can be observed in the Bulgarian and Romanian regions; however, the positions of regions show minor change in terms of social media use; while the performance of Romanian regions had been much more promising in 2016, the positions of the regions have swapped for three years. The three top performers are Estonia (EE00), Prague (CZ01) and Budapest (HU11). In general, the three categories have not undergone through significant changes. It can be confirmed that regions from the same country tend to group together, but compared to the 2016, results show that the distance among regions belonging to the same country has become larger. As in 2016, Czech and Polish regions can be found in the

'Average' category, Hungarian regions congregate in the groups of 'Average' and 'Leaders', and Slovakian regions along with most regions from the Baltic states are clustered in the 'Leaders'.

Figure 3.

MDS results of CSE-11 NUTS-2 regions, 2021



Note: ** Variable correlations at 95% confidence (p<0.050).

Source: Own elaboration.

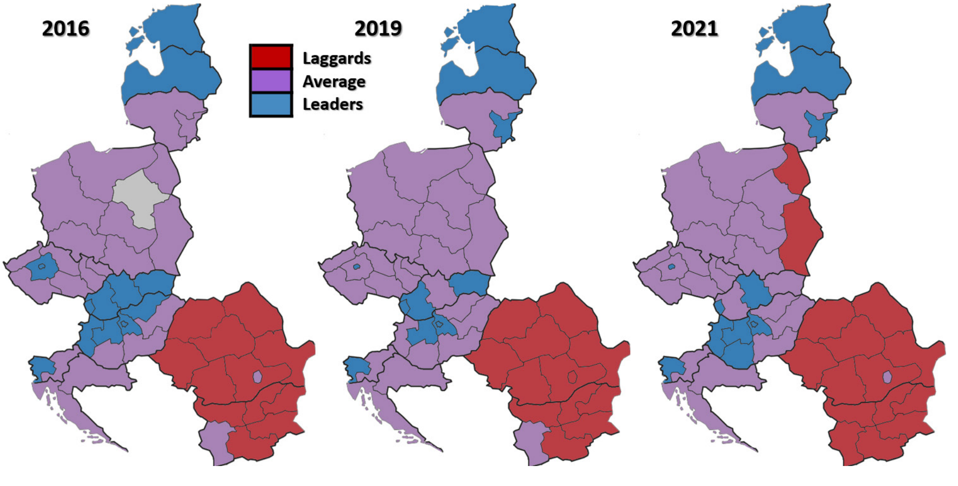
MDS results for the year 2021 are shown on Figure 3. The variable and dimension correlations have not changed sharply compared to the previous MDS results. Similarly to the previous cases, six indicators determine Dimension 1. Two indicators are compressed in Dimension 2. Among the top performers in Dimension 1, there are two outlier regions, Budapest (HU11) and Bratislava (SK01); however, Western Slovenia (SI01), Prague (CZ01) and Estonia (EE00) also show significant ICT-usage and ICT-infrastructure. Similarly to the 2016 and 2019 MDS results, relatively weak performance have been reported from the Bulgarian and Romanian countryside. In

Dimension 2, the highest values have been reported from the Hungarian regions, as well as Continental Croatia (HR04) which has been the top performer in the observed period. Interestingly, Bulgarian regions can be split into two groups, and the South-Central region has the largest lag among the CSE-11 regions.

Finally, after comparing the regional performance in Dimension 1 derived from the three MDS analyses, one can conclude that the classification of the 49 regions has not changed significantly in relative terms, only a few regions were reclassified. In general, the group of 'Laggards' consists of regions from the Bulgarian and Romanian countryside; 'Average' performers cover regions of Czechia apart from Prague, Poland, and Croatia, and partially regions of Hungary, Slovakia and Slovenia. The 'Leaders' are the capital regions (Budapest–HU11, Bratislava–SK01, Prague–CZ01, Vilnius–LT01) and their agglomeration and some neighbouring regions, as well as Estonia (EE00) and Latvia (LV00) (Figure 4).

Figure 4.

Classification of CSE-11 NUTS-2 regions based on Dimension 1



Note: Makroregion Województwo Mazowieckie (PL9) is shown without colour on the first map. Due to lack of data, the year 2016 is not considered.

Source: Own elaboration (design and cartography by the authors).

Summary and conclusions

In keeping with the key research aim presented in the introduction, this study empirically examined and evaluated the level of digital development among the regions of the CSE-11 countries through measuring the recent changes (2016–2021) in the ICT usage in households and by individuals through 7 ICT-related indicators. To reach this aim and find answers to the research questions of the study, we provided a thorough literature review on digital divide, and pointed out its three levels and influencing factors. In addition, we summarised the EU's strategic actions, initiatives and financial framework related to digital transformation as well as presented the DESI. Furthermore, we conducted multidimensional scaling to get an insight into the regional similarities and differences in the case study area.

The most important conclusions and findings of the research can be summed up as follows.

First, we can conclude that the digital divide is a relatively recent but urgent matter that emerged in an era when the infrastructure and usage of ICT enhanced, and access to the 'virtual world' became crucial in everyday life. As presented, the digital divide has three levels, reflecting the digital access (first level), digital capability (second level) and digital outcome (third level) one can gain from the process of digitalisation.

Furthermore, we concluded that the EU's actions in the field as well as policy objectives towards building a digital Europe have been of high priorities for the last couple of decades. The institutions of the EU have already recognised the need of bolstering digital transformation and policy making in the EU shifted its focus from providing only access to the Internet for the population to the provision of high-speed Internet and connectivity throughout the EU, together with the promotion of digital literacy and e-inclusion to narrow the digital gap between Member States and regions. The financial support frameworks (2014–2020 MFF, 2021–2027 MFF) also reflect the importance of digital development as huge funds from the EU budget have been allocated for digitalisation purposes.

MDS revealed that there is a relationship between the 7 ICT-related indicators. Besides, the dimension reduction resulted in solutions that do not differ significantly for the three years (2016, 2019, 2021). One can evidence that the first dimension contains the same six indicators (households with broadband access, daily use of internet, interaction with public authorities, internet banking, purchasing goods and services online, selling goods and services online), while the second dimension consists of the same indicator in 2016 and 2019 (participating in social networks) showing correlation with another variable (selling goods and services online) in 2021.

Important conclusion is that there is still a sharp divide among the regions of the European transition economies. We can conclude that regions belonging to the same country are more similar than different. Most of the regions have remained in the same category over the years; only some regions have moved to neighbouring categories. We can also conclude that regions of relatively low capacities in digitalisation tend to be the same ones with respect to all indicators. Mostly Bulgarian and Romanian regions are assigned to the 'Laggards' along Dimension 1. Estonia and Latvia can be labelled as 'Leaders'. Regions of Poland, Czechia, Lithuania, and Croatia can be primarily associated with the 'Average' cluster but partly with the 'Leaders', too. In the case of Hungary, Slovakia and Slovenia, a remarkable number of regions belong to the 'Leaders'. There is a clear dichotomy between the capital regions and the countryside, as capital regions tend to overperform the rest of the countries in general. This phenomenon can be witnessed, for example, in Bulgaria, Romania, Hungary, and Czechia.

During the assessment process we encountered some shortcomings that deserve further analysis.

First, there are some other ICT-related indicators provided by Eurostat that could have been involved in this study; however, we had to exclude them from this research as data were unavailable for some years (e.g., individuals who have never used a computer). Second, our original intention was to create an analysis focusing on every region in the EU27 context; however, data service delays are substantial in some Western and Southern European countries. Accordingly, we had to narrow down the case study area. Furthermore, ICT indicators are not available at the NUTS-2 (regional) level in some countries; for Poland, data on the NUTS-1 level were available. In addition, indicators available in Eurostat are not perfect for monitoring and evaluating digitalisation-related objectives as they are not in line with the priorities of the EU with respect to digital transformation.

Therefore, the impacts of the actions on EU level are harder to be detected. Accordingly, the entire measurement system can be amended and improved. Greater efforts in terms of data collection should be made to test other elements and features of digitalisation in the future.

We found several possible further research directions for a more detailed elaboration of the subject.

First, ICT-related indicators can be correlated with other indicators or indexes that capture economic prosperity, competitiveness, social exclusion, and sustainable development. Out of these, analysing linkages between social exclusion, social aspects and digitalisation should be particularly crucial research areas.

Another possible extension of the research could be carrying out empirical investigations at lower territorial units. For instance, cities or functional urban areas may serve as good case study fields for further primary research. Further research at LAU1 or LAU2 levels would reflect the existing dichotomies more precisely, and results derived from such investigations can be applied to practice and help policy makers design a creditable and sustainable ICT policy to empower the countryside as well as rural and peripheral areas, including sub-regions and settlements.

Furthermore, a possible direction for future research is in creating an empirical analysis with respect to every region of the European Union. In this study, the EU27 average emerged as a reference point. However, analysing digital divide and digital transformation throughout the 27 Member States along with their regions would be essential.

In addition, regional similarities might originate in political and institutional settings, depending on the legal background, public infrastructure, and social and cultural characteristics and traditions. These aspects worth further and in-depth analysis in the future.

The findings of the paper are of strong political relevance as they have important implications and political relevance not only for ICT policies but European sectoral and spatial development policies and policy areas as well. Decision-makers must be aware of the timely questions and topical issues of digital development, digital transformation and digital divide as digitalisation is crucial in driving economic growth, improving competitiveness, creating sustainable development as well as promoting sectoral and territorial development policies.

The results obtained might provide a reference for assessment and analysis of situation for European Union's sectoral and territorial policies and agendas (e.g., cohesion policy, regional development, regional convergence, social inclusion, digital economy and society, digital finance, e-business, e-commerce, e-governance). Adequate knowledge about the state of digital divide helps policy-makers identify further actions for improvement. For instance, considering the results of the multidimensional scaling, national governments and authorities can identify which regions should be supported in their digitalisation transition to narrow the digital gap. We believe that our findings have the potential to contribute to the ongoing discussion, evolving research, and fruitful debate on the subject.

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Appendix 1.

Geo-codes and geo-labels

Geo-codes	Geo-labels
BG31	Severozapaden
BG32	Severen tsentralen
BG33	Severoiztochen
BG34	Yugoiztochen
BG41	Yugozapaden
BG42	Yuzhen tsentralen
CZ01	Praha
CZ02	Strední Cechy
CZ03	Jihozápad
CZ04	Severozápad
CZ05	Severovýchod
CZ06	Jihovýchod
CZ07	Strední Morava
CZ08	Moravskoslezsko
EE00	Eesti
HR03	Jadranska Hrvatska
HR04	Kontinentalna Hrvatska
LV00	Latvija
LT01	Sostines regionas
LT02	Vidurio ir vakaru Lietuvos regionas
HU11	Budapest
HU12	Pest
HU21	Közép-Dunántúl
HU22	Nyugat-Dunántúl
HU23	Dél-Dunántúl
HU31	Észak-Magyarország
HU32	Észak-Alföld
HU33	Dél-Alföld
PL2	Makroregion Poludniowy
PL4	Makroregion Pólnocno-Zachodni
PL5	Makroregion Poludniowo-Zachodni
PL6	Makroregion Pólnocny
PL7	Makroregion Centralny
PL8	Makroregion Wschodni
PL9	Makroregion Województwo Mazowieckie
RO11	Nord-Vest
RO12	Centru
RO21	Nord-Est
RO22	Sud-Est
RO31	Sud – Muntenia

RO32	Bucuresti – Ilfov
RO41	Sud-Vest Oltenia
RO42	Vest
SI03	Vzhodna Slovenija
SI04	Zahodna Slovenija
SK01	Bratislavský kraj
SK02	Západné Slovensko
SK03	Stredné Slovensko
SK04	Východné Slovensko

Source: Own elaboration.

Appendix 2.

MDS test statistics: goodness of fit – stress and fit measures

Distance (interval)	Manhattan Distance (Minkowski p = 1)	Euclidean Distance (Minkowski p = 2)	Squared Euclidean Distance	Minkowski Distance (p = 3)	Chebychev Distance (Minkowski p→∞)
2016					
Normalized Raw Stress	0.0206	0.0287	0.0451	0.0342	0.0411
Stress – I.	0.1434	0.1695	0.2124	0.1849	0.2026
Stress – II.	0.2905	0.3604	0.3830	0.4066	0.4652
S-Stress	0.0221	0.0420	0.1034	0.0602	0.1011
Dispersion Accounted For (D.A.F.)	0.9794	0.9714	0.9549	0.9658	0.9590
Tucker's Coefficient of Convergence	0.9897	0.9855	0.9772	0.9828	0.9793
2019					
Normalized Raw Stress	0.0191	0.0206	0.0486	0.0206	0.0381
Stress – I.	0.1380	0.1436	0.2205	0.1433	0.1951
Stress – II.	0.2792	0.3065	0.4001	0.3164	0.4511
S-Stress	0.0259	0.0262	0.1000	0.0310	0.0850
Dispersion Accounted For (D.A.F.)	0.9810	0.9794	0.9514	0.9795	0.9620
Tucker's Coefficient of Convergence	0.9904	0.9896	0.9754	0.9897	0.9808
2021					
Normalized Raw Stress	0.0155	0.0207	0.0405	0.0262	0.0442
Stress – I.	0.1247	0.1440	0.2013	0.1618	0.2103
Stress – II.	0.2581	0.3103	0.3623	0.3559	0.4727
S-Stress	0.0217	0.0330	0.1003	0.0466	0.0973
Dispersion Accounted For (D.A.F.)	0.9845	0.9793	0.9595	0.9738	0.9558
Tucker's Coefficient of Convergence	0.9922	0.9896	0.9795	0.9868	0.9776

Source: Own elaboration based on SPSS output table.