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Spatial Assessment of the Digital Economy at the National and Sub-National Level

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Abstract: The study examines the concept of the digital economy, highlights the challenges in measuring it, and explores the development of indexes as a tool for assessing its growth and the effectiveness of policies and strategies. The proposed index is suitable for both national and sub-national spatial assessments, and it was tested and validated using examples from regions in Russia and European countries. The selected indicators comprehensively capture the geographical distribution of digital economic activity, including the concentration of digital businesses in specific regions, the availability of high-speed internet and mobile networks, the distribution of ICT-related jobs across different regions, and the level of e-commerce activity. The authors initiated an analysis and comparison of available data sources, which resulted in a list of indicators that allows for a sufficient assessment of the levels of digital economy development. The resulting index was used to assess the digital economy's development in regions in Russia and European countries. The top-ranking countries were Scandinavian, while Moscow dominated the rankings among Russian regions. The results also highlighted significant disparities in the development of the digital economy within Russia and Europe. The study's findings align with those of other international and domestic studies, confirming the reliability of the proposed methodology.

Keywords: digital economy; digital inequality; index; Europe; Russian regions

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1. Introduction

The term "digital economy" refers to economic activity that is the result of billions of everyday online transactions between people, businesses, devices, data, and processes. This includes e-commerce, online marketplaces, social network platforms, the sharing economy, and various industries and enterprises that have emerged because of the widespread use of the Internet and mobile technologies.

However, there are several obstacles to quantitatively assessing the digital economy. Firstly, there are various and divergent definitions of the digital economy. While this does not make measuring the digital economy impossible, it does complicate comparative analysis. Secondly, there is a problem with data quality, particularly in developing countries, where data collection either does not exist or is unreliable, and it is often difficult to distinguish between the digital and traditional sectors. This problem is exacerbated by further innovation, as data collection always lags behind technical progress. Thirdly, there is the issue of falling costs. Moore's Law and similar phenomena mean that the cost of computing power, memory, and other such resources is constantly decreasing. This also applies to information services. The emergence of free products, such as Wikipedia, is also significant, as they still add value. To account for this, appropriate adjustments to GDP calculations are necessary. Fourthly, there is the problem of virtuality. Many types of digital economic activity do not immediately create a finished product. Some services of this type may have an intermediate character at the b-to-b (business-to-business) level, making it difficult to calculate added value. In addition, digital services can be difficult to track, especially in the case of cross-border e-commerce or the digital phenomenon

of "consumer-as-producer". Finally, there are conceptual problems with using the Gross Domestic Product (GDP) indicator.

Developing a sub-national digital economy index is crucial for informing policy-making, guiding investment decisions, and fostering economic growth and development across regions. Collaboration and further research among countries can enhance the quality and comparability of regional digital economy assessments.

To tackle these challenges, our objective was to create an index applicable to both national and sub-national evaluations. We validated and tested the index using case studies from regions in Russia and European countries. While countries like China, India, and Brazil are also viable for this research, data collection limitations may impact the index's complexity and its comparability with European regions.

This study addresses a gap in the existing literature by providing a comprehensive and systematic approach to measuring and evaluating the digital economy at the regional level. The index developed in this study incorporates a range of indicators that capture various dimensions of digital economic activity, such as the availability of high-speed internet, concentration of digital businesses and startups, level of e-commerce activity, and digital skills of the population.

Overall, this study's contribution lies in its development of the Digital Economy Index, its application to evaluate the digital economy in diverse regions, and its insights into the underlying factors driving digital economy development. These findings have implications for policy interventions aimed at addressing digital inequalities and fostering economic growth in the digital era.

2. Literature Review

The term "digital economy" was first introduced in 1995 by computer scientist Nicholas Negroponte (1995). Initially, it only referred to commercial activity on the Internet; however, in recent years, the degree of digitization of economic activity has been constantly increasing. However, there is still no unified concept of the digital economy in science. Here are some examples of definitions of this concept: A form of economic activity that arises from billions of examples of network interactions between people, businesses, devices, data, and processes (Deloitte 2019). An economy that is dependent on digital technologies (European Commission 2014). We will rely on the definition of the World Bank: "The digital economy is a system of economic, social, and cultural relationships based on the use of digital information and communication technologies" (World Bank 2016).

Research with international comparisons began decades ago, simultaneously with efforts to measure digital inequality (Corrocher and Ordanini 2002; Selwyn 2004) within and between countries. Bergfeld and Weber (2011) noted that innovations from Europe have difficulty spreading to the United States and Asian countries. Dutta et al. (2017) also measured and compared factors related to ICT and calculated the "network readiness" for digital transformation, as well as economic performance outcomes such as the number of ICT-related patents in countries. Desruelle and Stančík (2014) compared "value-added" and "business expenditures on R&D (BERD)", as well as priority ICT patents, between the EU, the United States, Japan, China, Korea, and Taiwan, and identified the leading position of the United States in the industry. The OECD has addressed this issue and related policy issues. The organization publishes a wide range of reports, including "Digital Economy Papers" and "Digital Economy Outlooks". The OECD (2014) also released its set of indicators for comparing countries in its report "Measuring the digital economy". These indicators mainly concern infrastructure and investment in information and communication technologies. However, the OECD (2014, p. 15) identified several areas where further research is needed and that the measurement of ICT investment needs to be improved, including its connection with macroeconomic indicators.

Developing indexes is a vital tool in assessing the digital economy's development, allowing for international comparisons, and providing insights into the effectiveness of policies and strategies implemented by governments and organizations. For international

comparisons, the European Commission developed the Index of Digital Economy and Society (I-DESI) in 2016 (European Commission 2018). The index allows for a comparison of the development of the digital economy in Russia and countries within the European Union, as well as Iceland, Japan, the United States, and other countries. The I-DESI index is calculated for 28 EU member countries and 15 non-EU countries using 18 key indicators that are significant and statistically supported in most countries in the world.

The McKinsey Global Institute (MGI) (2015) ranks industries according to the digitization index based on the proportion of IT expenses in operating expenses, the weight of IT in firm assets, and the proportion of tasks that are computerized. Finance, media, and advanced manufacturing are considered highly digital. Moderately digitized sectors include retail, transportation, and hospitality, which include digital leaders such as Amazon, Uber, and Airbnb (Jensen 2007).

There are numerous sub-national research studies of the digital economy that have been conducted across different regions and countries. One sub-national regional index that measures the state of the digital economy in Brazil is the "Índice Cidades Amigas da Internet" (Brazilian Network Information Center 2021). The index evaluates the quality and availability of internet infrastructure and services in Brazilian cities, considering factors such as broadband access, the availability of public Wi-Fi, and the level of digital literacy among the population. The index also assesses the level of engagement and commitment of local authorities to promote the development of the digital economy in their cities.

The Mexican Institute for Competitiveness (IMCO) published the "Índice de Competitividad Digital Estatal" (State Digital Competitiveness Index) Instituto Mexicano para la Competitividad (IMCO) 2023). The index evaluates the level of digital competitiveness of Mexican states, taking into account factors such as the quality and availability of digital infrastructure, the use of digital technologies by businesses and government, the level of digital skills and literacy among the population, and the development of digital services and startups.

The "India Digital States Index", a sub-national regional index, is jointly produced by the Internet and Mobile Association of India (IAMAI) and consulting firm Coeus Age Consulting (2019). The index considers various factors such as the availability and quality of digital infrastructure, the level of digital literacy and skills among the population, the use of digital technologies by businesses and the government, and the development of digital services and startups. By evaluating these factors, the index provides a comprehensive assessment of the level of digital development and adoption in Indian states.

There is a lack of research on the geography of the digital economy in Russia. Work in this area is being carried out at the Higher School of Economics' ISSEK NRU HSE. In collaboration with the Ministry of Communications and Mass Media of the Russian Federation and Rosstat, they publish statistical collections that provide essential indicators of the digital economy's development in Russia. These publications present the main indicators of the development of the digital economy in Russia, the country's position in international ratings, and some technological trends that determine the trends in the development of the information society. These bulletins include "The Contribution of Digitalization to the Growth of the Russian Economy", "The Information Industry in Russia", "Personnel for the Digital Economy", and others.

One of the clear gaps in existing research is the lack of methodologies that allow for analysis at both the international and regional levels. In the work of A. Sidorov and P. Senchenko (Sidorov and Senchenko 2020), a methodology for assessment is proposed using an index of digitalization level, which includes an assessment of the digital economy, digital government, and digital citizenship based on 13 indicators. According to their calculations, Russia, along with Bulgaria, is in the group with a below-average level. However, some regions, such as St. Petersburg, show better results than some European countries, such as France and the United Kingdom, while Moscow occupies an even higher position, surpassing Germany as well.

Despite the research mentioned in the paragraphs above, there is still a significant gap in measuring the regional and geographic aspects of the digital economy. The lack of sub-national geographic research hinders a comprehensive assessment of the socio-economic impact of information and communication technologies (ICT) on regional and local development, as well as the ability to predict potential effects. It should be noted that none of the existing methods for assessing the level of digitalization of subnational entities is universally applicable due to several circumstances. Among them are differences in the collection of statistical data at the regional and country levels, a deficit of regional data on digitalization and the digital economy, and a low level of adaptation of international approaches to the existing information system. These limitations seriously affect the quality of all existing regional assessment methods. In Russia, where regions differ in scale, population, and diversity of socio-economic conditions no less than individual countries, such comparisons are particularly relevant.

3. Materials and Methods

In the first stage of the study, criteria for selecting indicators were determined. The digital economy encompasses a broad range of sectors, activities, and technologies that are interconnected and reliant on digital systems. While it is challenging to establish rigid boundaries due to the dynamic nature of the digital economy, we can provide an overview of the main elements typically included within its scope. Spatial indicators of the digital economy should comprehensively characterize the geographical distribution of digital economic activity. For example:

- Concentration of digital business in certain regions;
- Availability of high-speed internet and mobile networks;
- Distribution of ICT-related jobs across different regions;
- Degree of digitalization of the economy in different sectors;
- Level of e-commerce activity;
- Number of active internet users;
- Degree of digital skills and competencies among the population in different areas;
- Level of digital government development in different regions.

It's important to note that the digital economy is a rapidly evolving field, and new sectors, activities, and technologies continually emerge. The scope and boundaries may expand or change over time as technological advancements and market dynamics evolve.

After identifying the main directions, we initiated an analysis and comparison of available data sources for analysis. The indicators incorporated in the Digital Economy Index should adhere to certain criteria: they should be collected periodically to facilitate their monitoring function, ensuring regular updates and assessments; they should be recognized as relevant metrics within their respective policy domains; and they should be collected consistently, employing the same standardized methodology. However, the limited availability of regional data compared to international data posed a challenge in incorporating certain indicators into the assessment. Additionally, the absence of crucial indicators for evaluation at the regional level in Russia, which are not included in international statistics, further contributed to the limitations of the study. For instance, the indicator "Share of electronic document flow between state authorities in the total volume of interdepartmental document flow" is not collected in EU countries, and there are no reasonably comparable analogues. Additionally, some indicators were similar; however, their methodologies showed that it was incorrect to compare these data with each other, such as the "Share of organizations using means of protection of information transmitted over global networks in the total number of surveyed organizations" and the indicator "Businesses with formal policies to manage ICT risks". As a result, we obtained a list of indicators that allows for a sufficient assessment and comparison of the levels of digital economy development. The sources of data for Russian regions were collections: Indicators of the Digital Economy: 2020 (Abdrakhmanova et al. 2020); Information Society in the

Russian Federation: 2020 (Federal State Statistics Service 2020). Data sources for European countries: Eurostat (2019), OECD. Stat.

Based on determined criteria and available data, we have compiled five sub-indices characterizing the most important components of the digital economy. First, it is the concentration of digital businesses. The high concentration of digital businesses may indicate the development and competitiveness of the digital economy in the region. Assessing the concentration of digital businesses is important for understanding development and competition in the digital economy, determining the level of development of digital infrastructure, and ensuring economic equality. The concentration of digital businesses can be assessed using the indicator of the number of employees in the IT sector. The higher the number of employees in the IT sector, the higher the degree of concentration of digital enterprises and companies in that area.

The level of development of broadband access is a critical indicator for assessing the digital economy as it reflects the availability and quality of digital infrastructure, connectivity, and the potential for digital innovation and inclusion.

The indicator of online goods and services consumption activity reflects both the level of development of these services and the readiness of the population to consume them in such a form; for this, there must be access, skills, and financial ability.

Assessing digital inequality in computer skills is important for evaluating the digital economy because the digital economy requires widespread digital skills among the population. Assessing digital inequality in computer skills helps identify areas where insufficient digital skill proficiency may hinder the development of the digital economy and reduce a country's or region's competitiveness. Moreover, digital inequality in computer skills can lead to the exclusion of certain population groups from the benefits and opportunities offered by the digital economy.

The level of business digitalization refers to the extent to which a business or organization has incorporated digital technologies and processes into its operations and overall strategy. This includes the use of digital tools and platforms to enhance communication, automate tasks, analyze data, and improve overall efficiency and productivity. A high level of digitalization may indicate that a business is more competitive, adaptable, and responsive to changing market conditions, while a low level of digitalization may leave a business at a disadvantage in today's rapidly evolving digital landscape.

As a result, a database of indicators (Table 1) for the year 2019 was prepared, which can be used to compare Russian regions and countries.

The index utilizes equal weights for each of its dimensions. Within each dimension, all individual indicators are given equal importance and are therefore weighted equally. taking simple arithmetic averages of the normalized scores. Normalized indicators were calculated using Formula (1) (Tikunov 1997):

$$\hat{x}_{ij} = \frac{|x_{ij} - \overset{0}{x}_j|}{|_{max/min}x - \overset{0}{x}_j|},\ I = 1,\ 2,\ 3,\ \ldots,\ N;\ j = 1,\ 2,\ 3,\ \ldots,\ M, \tag{1}$$

where $\overset{0}{x}$ is the worst value (for each indicator) encountered; ${}_{max/min}{}^{x}$—are the most different values from $\overset{0}{x}$; N is the number of territorial units studied; M is the number of indicators used for calculations. The aim of this normalization is to convert the indicator into a deviation from the given best or worst value. The normalized indicators obtained are limited by the range [0, 1].

Table 1. Indicators that have been selected to build the assessment.

Sub-Index	Indicator for Russian Regions	Indicator for European Countries
Concentration of digital business	Share of people employed in ICT in the total employed population	Percentage of the ICT personnel in total employment
Level of development of broadband access	Subscribers of fixed broadband Internet access per 100 people	Fixed broadband subscriptions, Total, Per 100 inhabitants
	Subscribers of mobile broadband Internet access per 100 people	Mobile broadband subscriptions, Total, Per 100 inhabitants
Digital Government	The share of the population who used the Internet to receive state and municipal services, in the total population	Internet use: interaction with public authorities (last 12 months), Percentage of individuals
Consumption of goods and services online	The share of the population who used the Internet to order goods and (or) services, in the total population	Individuals who have purchased online (%)
	Population using the Internet to order popular goods and services in the regions: Clothing, footwear, sporting goods (Rosstat gives a percentage of the population using the Internet to order goods and services. This and similar indicators must be converted to a percentage of the total population)	Individuals who have purchased online clothing, footwear, or sporting goods (%)
	Population using the Internet to order popular goods and services in the regions: Financial services (banking services, money transfers, insurance services, operations with shares and other securities, etc.)	Individuals who have purchased online financial products (%)
	Population using the Internet to order popular goods and services in the regions: Household items (furniture, dishes, cutlery, bedding, interior items, toys, etc.)	Individuals who have purchased online food, groceries. . ., cosmetics (%)
Digital inequality	The skills of personal computer use in the regions: Working with a text editor (percentage of the total population using a personal computer)	Individuals who have created presentations or documents integrating text, pictures, tables, or charts. Percentage of individuals (This and similar indicators must be converted to a percentage of the total population using a personal computer)
	The skills of personal computer use in the regions: Working with spreadsheets (percentage of the total population using a personal computer)	Individuals who used spreadsheet software, Percentage of individuals
	The skills of personal computer use in the regions: Transferring files between a computer and peripheral devices (digital camera, player, mobile phone) (percentage of the total population using a personal computer)	Individuals who have copied or moved a file or folder Percentage of individuals

Table 1. *Cont.*

Sub-Index	Indicator for Russian Regions	Indicator for European Countries
The level of business digitalization	The share of organizations using digital technologies in the total number of organizations, percentage: broadband internet	Businesses with a broadband connection—includes both fixed and mobile (%)
	The share of organizations using digital technologies in the total number of organizations, percentage: cloud computing services	Percentage of enterprises purchasing cloud computing services used over the internet
	The share of organizations using digital technologies in the total number of organizations, in percentage: RFID	Enterprises using radio frequency identification (RFID) instrument
	The share of organizations using digital technologies in the total number of organizations, in percentage: ERP	Businesses using ERP (Enterprise Resource Planning) software (%)
	The share of organizations using digital technologies in the total number of organizations, in percentage: Electronic sales	Enterprises having received orders online (at least 1%)—% of enterprises
	Organizations with a website (percentage of total organizations)	Enterprises with a website, Percentage of enterprises

The process of combining indicators into dimensions and combining dimensions into the overall index involves comparing the indicators of all territorial units with a hypothetical unit characterized by values $\overset{0}{x}$. Their ranking is then determined. In this case, it was carried out using Euclidean distances (d^0) as a measure of the proximity of all territorial units to a hypothetical unit that has the worst values $\overset{0}{x}$ across the entire set of indicators. A small distance is equivalent to a large similarity (Nardo et al. 2005). This allows for emphasizing the influence of individual coordinates that have abnormally large distances since they are squared. The application of this measure required processing the information array using the principal component method to orthogonalize and "fold" the system of indicators. The obtained column vector values of d^0 as integral assessment characteristics are additionally normalized for convenience of further analysis using Formula (2):

$$\hat{d}_i^o = \frac{d_i^0 - {}_{min}d^0}{{}_{max}d^0 - {}_{min}d^0},\ i = 1,\ 2,\ 3,\ \ldots,\ n. \tag{2}$$

The value of d^0 varies within the range from zero to one. Zero corresponds to the worst complex assessment, and one corresponds to the best.

4. Results

We utilized the collected database to create a series of maps that assess the spatial development of the digital economy in Russia and Europe. Most indicators indicate that Russia performs at an average or below-average level. Let's look at each indicator in detail.

The share of those employed in ICT (Figure 1) in Russia is on average 1.7%, which is on par with Greece (1.54%) and Montenegro (2%). The higher the percentage, the more advanced and prosperous the territory is in technological terms. In the regional breakdown, we observe a wide range of indicators. Moscow is on par with Norway—3.18%; Oryol Oblast and St. Petersburg are on par with Bulgaria—3% of those employed in the economy; Novosibirsk Oblast is on par with Poland—2.7%. Most regions approach Turkey in terms of the indicator (1% employed). The least number of people work in the ICT sector in the Kirov Oblast (0.47%), Amur Oblast (0.49%), and the Republic of Ingushetia (0.56%). As in recent years, due to dynamic development in the industry, there has been a shortage of personnel, and large cities are actively attracting qualified personnel to themselves. Most regions, even with a good resource base in the form of specialized universities, cannot compete in

terms of salaries in the industry with Moscow, St. Petersburg, and, unfortunately, with European countries.

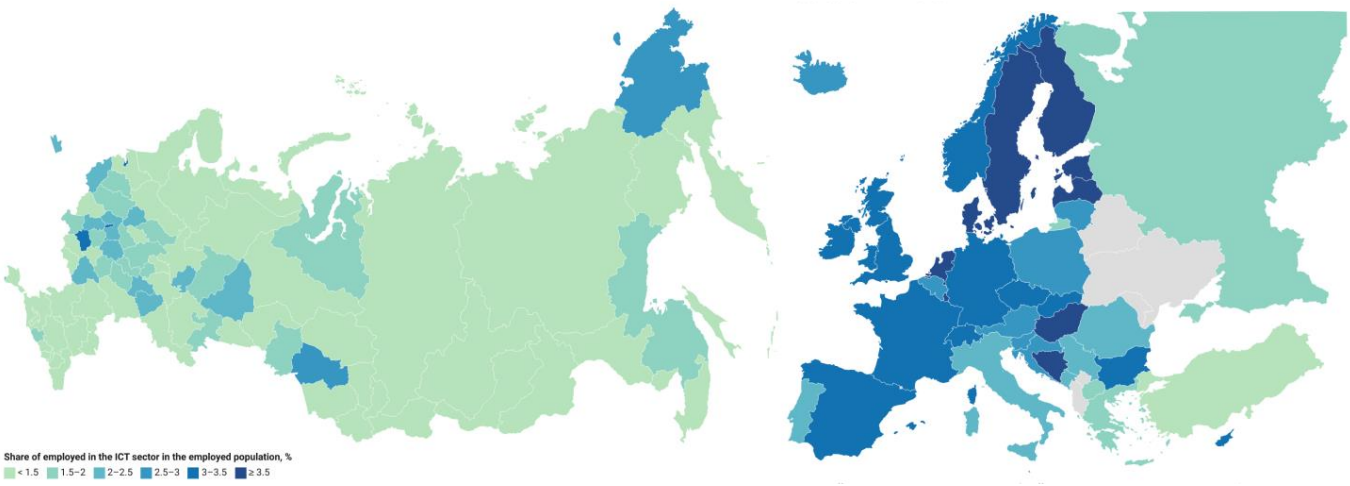

Figure 1. The share of people employed in ICT, 2019.

The proportion of the population using the Internet to obtain government services (Figure 2) is an indicator that simultaneously speaks to the government's interest in digital transformation and people's readiness for such services. In terms of the share of the population using the Internet to access government services, Russia is at an average level for European countries—56.5%, between Spain (58%) and Lithuania (55%). At the same time, the regions of Russia vary significantly. The Yamalo-Nenets Autonomous District is on par with leading countries—88.9%, like Iceland (89%, second place in Europe) and Finland (87%, third place). The Moscow Oblast, the Republic of Bashkortostan, Moscow, and the Saratov Oblast lag Sweden (86%, fifth place in Europe) but outstrip the Netherlands (81%, sixth place). Outsiders include Romania (12%), the Magadan Oblast (15%), Bosnia and Herzegovina (18%), and the Jewish Autonomous Oblast (20.2%).

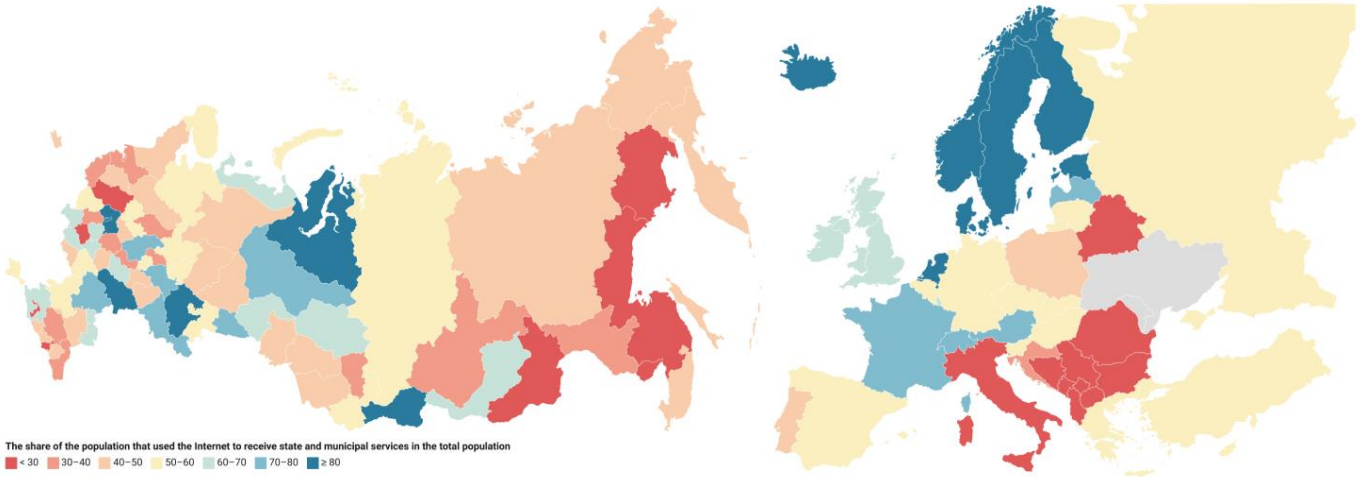

Figure 2. The share of the population using the Internet to access government services, 2019.

The level of broadband development in Russia (Figure 3) is lower than in Western European countries—0.53 points, which is comparable to Croatia's level (0.54). It is logical that Moscow (0.78) is high up, at the same level as Sweden (0.78) and Iceland (0.76). Infrastructure indicators are often higher in cities. The Novosibirsk region (0.70) and St. Petersburg (0.69) are at a high level, on par with Germany (0.71), Latvia (0.69), and Belgium (0.69). The lowest level of broadband infrastructure development is observed

in national republics, especially in the North Caucasus, in the Republics of Ingushetia (0.16), Dagestan (0.20), and Tuva (0.22). This is largely due to the inaccessibility of many settlements, the general level of infrastructure, and the level of income of the population. It is worth noting separately the Republic of Crimea and Sevastopol, where, according to official data, the indicators are very low. However, they do not reflect the real picture, as in 2019, due to sanctions, many services, especially mobile communication, were obtained by residents through bypass routes; for example, free roaming was provided by mobile operators registered on the mainland.

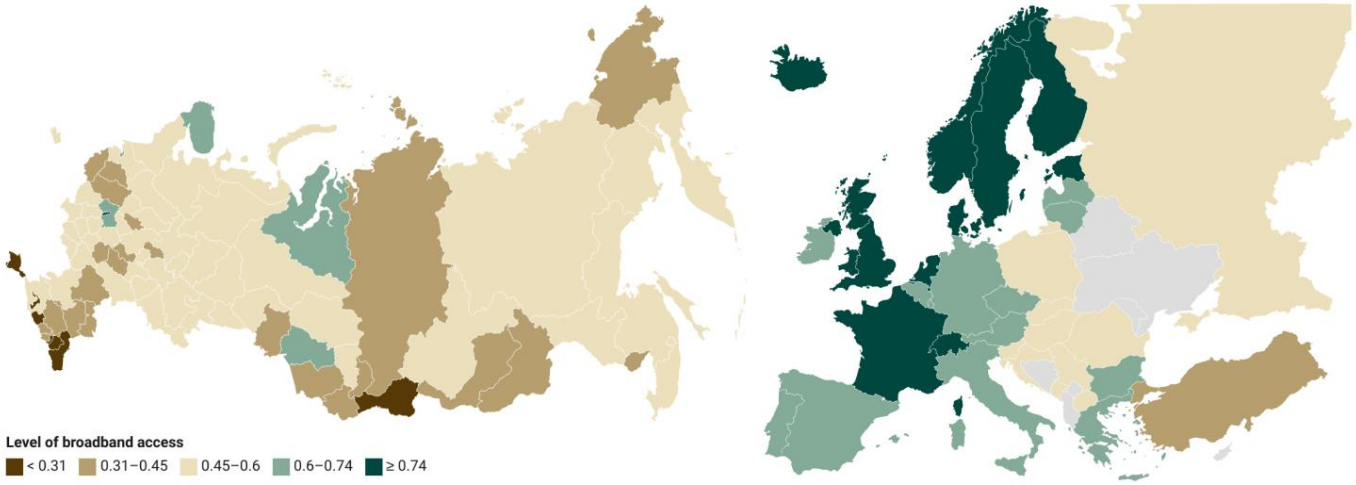

Figure 3. The level of broadband access in 2019.

European countries differ significantly from each other in terms of online goods and services consumption activity (Figure 4), and Russia is at a level between Portugal (0.27) and Greece (0.24). Within Russia, regions are scattered no less than in European countries. The Yamalo-Nenets and Chukotka Autonomous Districts are at the same level of activity as Denmark (0.72). The Murmansk region (0.54) and the Nenets Autonomous District (0.54) are slightly ahead of France (0.50). Moscow shares a line with Luxembourg (0.49). The lowest population activity in online consumption is observed in the Republics of North Ossetia-Alania (0.01), Kalmykia (0.02), Dagestan (0.03), and Adygea (0.03). Among the European countries considered, the worst indicators of activity are Montenegro (0.03) and North Macedonia (0.9).

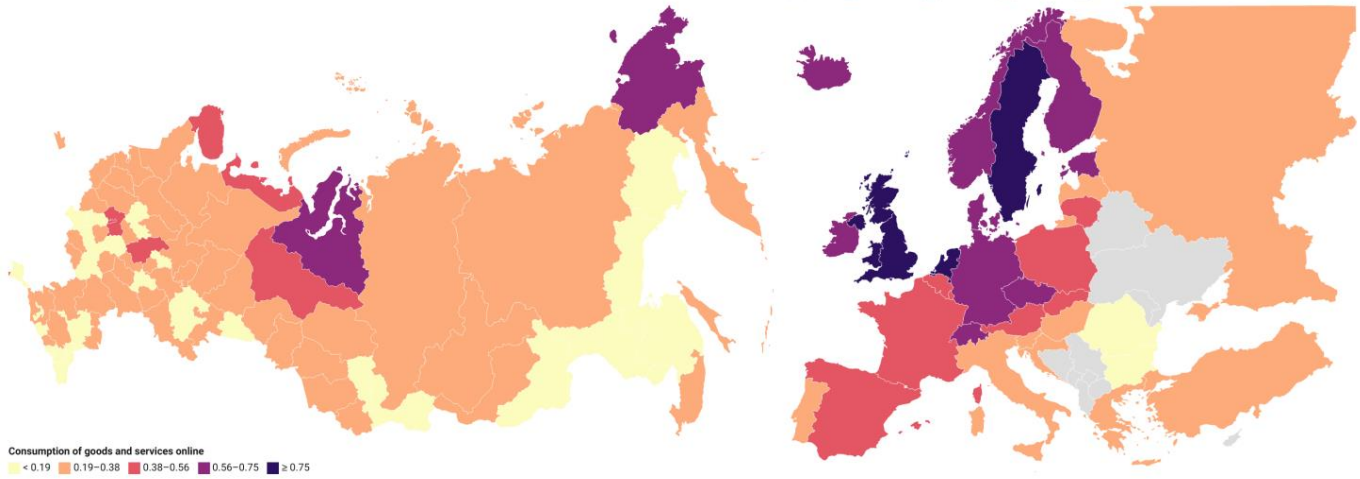

Figure 4. The level of online goods and services consumption, 2019.

According to our assessment of the population's computer skills (Figure 5), the Chukotka Autonomous Okrug has the highest level of computer literacy among all regions, with a score of 0.705, which is significantly higher than that of the United Kingdom (0.678). Following the Okrug are Moscow (0.704) and the Tyumen Oblast (0.619). On the other hand, the Chechen Republic has the lowest score among all included regions and countries—0.132. Other regions with relatively low scores include the Republic of Crimea (0.132), Novgorod Oblast (0.260), and the Republic of Dagestan (0.268). Among the included countries, Iceland has the highest score (0.848), followed by Switzerland with a score of 0.776, Norway (0.761), and the Netherlands (0.753). North Macedonia has the lowest score (0.232), which is comparable to Novgorod Oblast (0.260). Bulgaria (0.251) and Romania (0.361) have slightly higher computer literacy rates.

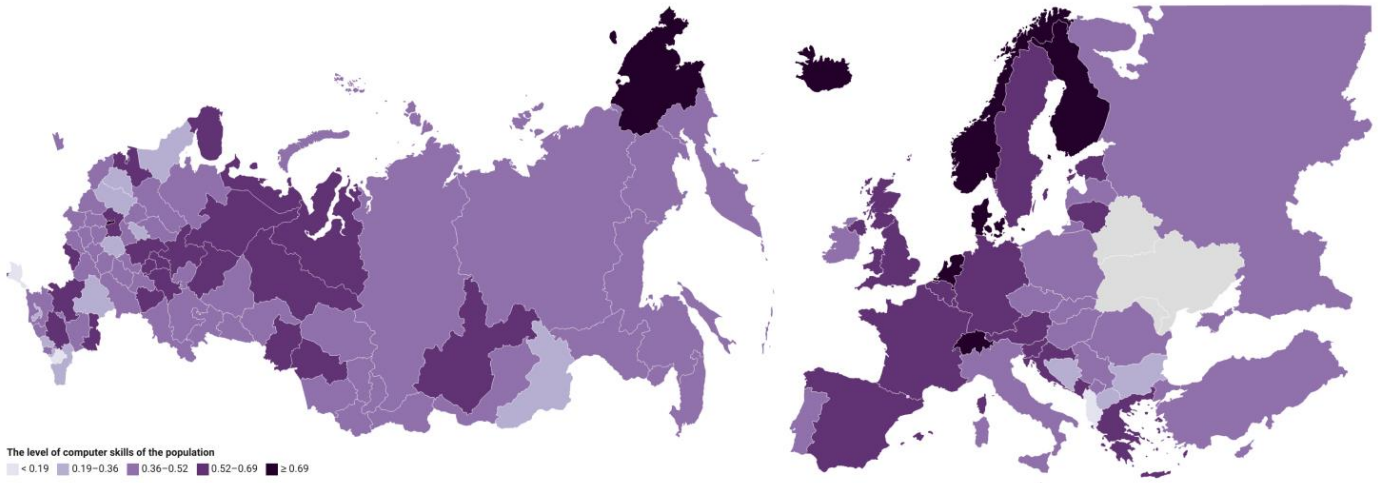

Figure 5. The level of computer skills of the population, 2019.

The level of digitalization of business in Russia (Figure 6) is 0.354, which is lower than most European countries except Greece (0.319), Romania, and North Macedonia (0.278). Even Moscow (0.500), which is at the level of leading countries in other indicators, is lower than Portugal (0.503). Other regions with better performances in Russia are St. Petersburg (0.469) and the Republic of Tatarstan (0.458). The lowest level of digitalization of business is in the Republics of Dagestan (0.027), North Ossetia-Alania (0.142), and Tuva (0.193). Romania has the worst performance among European countries (0.277).

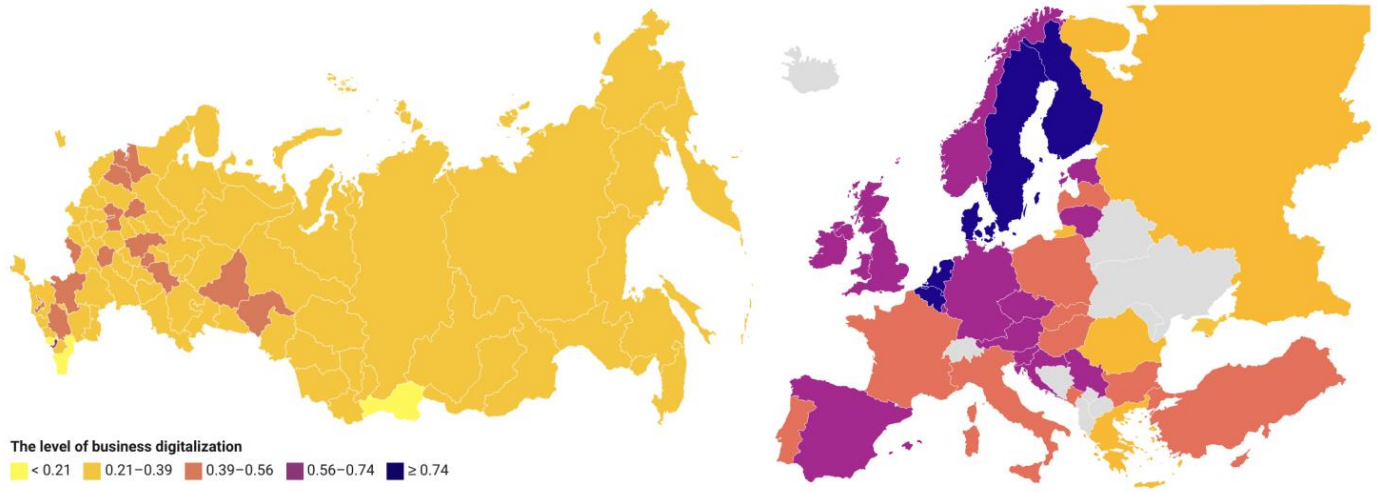

Figure 6. The level of business digitalization, 2019.

A comprehensive assessment (Figure 7) provides valuable insights into the current state of digital economy development in both Russia and Europe. The top-ranking countries are Scandinavian: the Netherlands (0.89), Sweden (0.87), and Denmark (0.86). They are all known for their progressive and innovative approach to technology and digitalization. In Russia, Moscow, a city that has been investing heavily in digital infrastructure and innovation, dominated the rankings with a significant lead (0.70), with a digital economy development level comparable to that of the United Kingdom (0.75). The Yamalo-Nenets Autonomous Okrug (0.62) followed closely behind Moscow, slightly ahead of Spain (0.60). The Moscow region (0.56) ranked third among the regions, at the same level as Latvia (0.58) and Slovakia (0.56). However, the results also highlight a stark contrast between the highest- and lowest-ranking regions and countries. Bulgaria (0.34), Romania (0.26), and North Macedonia (0.24) had the lowest index values in Europe. The Chechen Republic (0.16), the Republic of Crimea (0.13), and the Republic of Dagestan (0.12) are the Russian regions with the lowest level of digital economy development, ranking at the bottom of the list. It shows that there are dramatically significant disparities in the development of the digital economy within Russia itself.

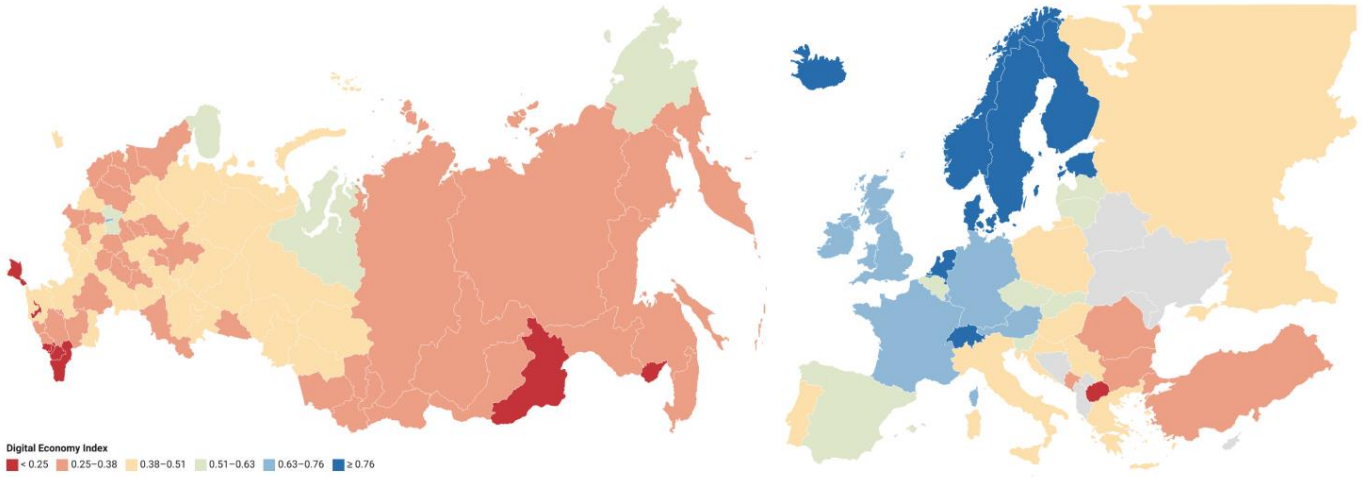

Figure 7. Digital Economy Index, 2019.

5. Discussion

The findings of this study provide important insights into the current state of digital economy development at both the national and sub-national levels in Russia and Europe. The results reveal significant disparities in the development of the digital economy within Russia, with certain regions falling behind others. Additionally, the study highlights that countries achieving high rankings in digital economy development are those that have made substantial investments in digital infrastructure and embraced progressive and innovative approaches to technology and digitalization.

The development of the Digital Economy Index in this study offers several advantages that deserve emphasis. Firstly, the methodology enables a detailed analysis by capturing sub-national variations in the digital economy. This allows for a comprehensive assessment of digital economy development at the regional level, shedding light on the specific strengths and weaknesses of different areas within a country. Such granular analysis facilitates targeted policy interventions that can address the unique needs and challenges of each region.

Second, the indexes enable comparisons of the digital economy's development between regions within a country and even across different countries. This comparative perspective allows policymakers and researchers to identify regional disparities and benchmark performance against international counterparts. It provides valuable insights for policy-making as well as opportunities for knowledge sharing and best practices exchange between regions and countries.

Third, the indexes are directly relevant to policy-making and investment decisions. They provide policymakers with evidence-based insights into the state of the digital economy, highlighting areas for improvement and potential opportunities for intervention. By utilizing these indexes, policymakers can make informed decisions and design targeted strategies to foster digitalization, address digital inequalities, and promote economic growth.

The main limitations of this methodology can be identified. One of the primary limitations is the availability of data. There is often a deficit of regional data on digitalization and the digital economy and a low level of adaptation of international approaches to the existing information system. This can significantly affect the quality of all existing regional assessment methods. Moreover, there are differences in the collection of statistical data at the regional and country levels, which can make it difficult to compare regions across countries.

Second, there are limitations to indicators. Some important indicators for evaluating the digital economy's development are not available at the regional level in some countries. For example, the indicator "Share of electronic document flow between state authorities" is not collected in EU countries, and there are no reasonably comparable analogues. Additionally, some indicators are not directly comparable due to differences in methodology.

Digital Economy Index scores can vary significantly due to different ways of normalizing, weighting, and aggregating the individual indicators (Ekel et al. 2022; Greco et al. 2019). These variations bring uncertainties about the results and impact the ability of the index to capture the construct of the multidimensional phenomenon (Dialga and Giang 2017; Bernardes et al. 2022).

The method may not capture all relevant aspects of the digital economy's development. For example, the method focuses on spatial indicators and may not capture other important aspects such as the impact of digitalization on productivity, innovation, and economic growth.

The limitations of existing regional assessment methods underscore the importance of developing new and more comprehensive indices to assess digital economy development at the sub-national level. Such indices can inform policy-making and investment decisions, as well as help promote economic growth and development in different regions. In addition, the study suggests further research and collaboration among countries to enhance data collection processes, thereby improving the quality and comparability of regional assessments in the field of the digital economy.

The developed indexes are designed to be scalable and adaptable, making them suitable for application in different regions and countries. While the study focuses on regions in Russia and European countries, the methodology and indicators can be adjusted to accommodate other regions globally. While our primary focus remains on these regions, we acknowledge the potential for the indexes to be adapted and applied in large countries like China, India, and Brazil. We have highlighted the importance of data collection and comparability in ensuring the successful application of the indexes across different regions.

Future research directions could include expanding the scope of the index to include more indicators that capture different aspects of the digital economy's development. Additionally, research could focus on identifying the factors that contribute to the disparities in digital economy development within countries and regions and developing strategies to address these disparities. The analysis of uncertainty and the linkage of the Digital Economy Index to external variables will be directions for our future research to improve the reliability and robustness of the index. Additionally, exploring the relationship between the Digital Economy Index and external variables such as economic growth, innovation, and social well-being will provide valuable insights into the broader impacts and implications of digitalization. This future research will allow us to gain a deeper understanding of how the digital economy interacts with external factors, enabling policymakers and stakeholders to formulate effective strategies and address potential challenges more efficiently.

Overall, the findings of this study provide a valuable contribution to the field of digital economy development, highlighting the importance of investing in digital infrastructure and adopting a progressive and innovative approach to technology and digitalization to promote economic growth and development.

6. Conclusions

In conclusion, the digital economy presents significant challenges for traditional economic analysis due to unresolved difficulties in measuring its size accurately. The lack of research, particularly at the sub-national level, on the spatial aspects of this transformation further compounds the issue. The role of geography remains significant, and while spatial barriers are decreasing, understanding the social and economic impact of ICT on regional and local development remains a challenge. More research is needed to fully measure the relationship between the digital transformation of the economy and innovation centers' relative development and the resulting impact on prosperity. The new Digital Economy Index offers a comprehensive, granular, and comparative perspective on the digital economy at the regional level. Their policy relevance, scalability, and adaptability make them valuable tools for policymakers and researchers seeking to understand, assess, and foster digital economy development. The indexes serve as a monitoring and evaluation tool for policy initiatives aimed at promoting the digital economy. By periodically assessing the performance of different regions based on the indexes, policymakers can track progress, identify areas for improvement, and adjust policies and interventions accordingly. This iterative process of monitoring and evaluation allows for continuous improvement in policy implementation and ensures that resources are directed where they are most needed. The granular analysis provided by the indexes allows policymakers to identify specific regions or areas that require targeted policy interventions. By understanding the strengths and weaknesses of different regions in terms of digital economy development, policymakers can design tailored strategies and initiatives to address the specific challenges and opportunities in each region. This targeted approach can lead to more effective policy interventions and better outcomes in terms of digital transformation and economic growth. This is especially important for big countries like Russia, where regions vary greatly in terms of scale, population, and socio-economic conditions.

It is clear that digitalization varies significantly among regions and countries in Russia and Europe, with some areas performing at a high level and others lagging. These variations are influenced by a range of factors, including infrastructure, income levels, and computer literacy. Overall, the results of the assessment emphasize the importance of investing in digital infrastructure and innovation to remain competitive and promote economic growth in both Russia and Europe. The developed Digital Economy Index can be used to assess the impact of policy interventions on the digital economy over time. By tracking changes in the indexes before and after the implementation of specific policies or initiatives, policymakers can evaluate the effectiveness of their interventions and make data-driven adjustments. This policy impact assessment helps policymakers refine their strategies and ensure that policy interventions are achieving the desired outcomes.

Overall, the application of the developed indexes in policy-making and national governance enables evidence-based decision-making, targeted interventions, monitoring and evaluation, benchmarking, and policy impact assessment. By leveraging these indexes, policymakers can effectively steer the digital economy agenda, promote inclusive growth, and ensure that the benefits of digital transformation are equitably distributed across regions.

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References

Abdrakhmanova, Gulnara I., Kirill O. Vishnevsky, and Leonid M. Gokhberg. 2020. *Indicators of the Digital Economy: 2020: Statistical Collection*. Moscow: National Research University Higher School of Economics.

Bergfeld, Marc-Michael, and Felix-Michael Weber. 2011. Dynasties of Innovation: Highly Performing German Family Firms and the Owners' Role for Innovation. *International Journal of Entrepreneurship and Innovation Management* 13: 80–94. [CrossRef]

Bernardes, Patrícia, Petr Iakovlevitch Ekel, Sérgio Fernando Loureiro Rezende, Joel Gomes Pereira Júnior, Angélica Cidália Gouveia dos Santos, Maurício Andrade Rodrigues da Costa, Rafael Lopes Carvalhais, and Matheus Pereira Libório. 2022. Cost of doing business index in Latin America. *Quality & Quantity* 56: 2233–52. [CrossRef]

Brazilian Network Information Center. 2021. Friendly Cities of the Internet Index. Available online: https://www.telesintese.com.br/wp-content/uploads/2021/09/Ranking-Cidades-Amigas-2021.pdf (accessed on 3 April 2023).

Coeus Age Consulting. 2019. *Digital States of India. A Comparative Analysis*. Report. Gurgaon: Coeus Age.

Corrocher, Nicoletta, and Andrea Ordanini. 2002. Measuring the Digital Divide: A Framework for the Analysis of Cross-Country Differences. *Journal of Information Technology* 17: 9–19. [CrossRef]

Deloitte. 2019. What Is Digital Economy? Available online: https://www2.deloitte.com/mt/en/pages/technology/articles/mt-what-is-digital-economy.html (accessed on 13 February 2023).

Desruelle, Paul, and Juraj Stančík. 2014. Characterizing and comparing the evolution of the major global economies in information and communication technologies. *Telecommunications Policy* 38: 1065–79. [CrossRef]

Dialga, Issaka, and Le Thi Hang Giang. 2017. Highlighting Methodological Limitations in the Steps of Composite Indicators Construction. *Social Indicators Research* 131: 441–65. [CrossRef]

Dutta, Soumitra, Roberto Escalona Reynoso, Jeffrey Litner, Bruno Lanvin, Francis Guadagno, and Sacha WunschVincent. 2017. *Global Innovation Index 2017: Innovation Feeding the World*. Edited by Soumitra Dutta, Bruno Lanvin and Sacha Wunsch-Vincent. Ithaca: Fontainebleau. Geneva: Cornell, INSEAD, and WIPO.

Ekel, Petr, Patrícia Bernardes, Gláucia Maria Vasconcellos Vale, and Matheus Pereira Libório. 2022. South American business environment cost index: Reforms for Brazil. *International Journal of Business Environment* 13: 212–33.

European Commission. 2014. Expert Group on Taxation of the Digital Economy. Available online: https://taxation-customs.ec.europa.eu/expert-group-taxation-digital-economy_en (accessed on 13 February 2023).

European Commission. 2018. Digital Economy and Society Index (DESI). Available online: https://eufordigital.eu/wp-content/uploads/2019/10/Digital-Economy-and-Society-Index-DESI-2018.pdf (accessed on 13 February 2023).

Eurostat. 2019. Eurostat Metadata. EU. Available online: https://ec.europa.eu/eurostat/data/database (accessed on 13 February 2023).

Federal State Statistics Service. 2020. *Information Society in the Russian Federation. 2020: Statistical Compendium. Electronic Text, 33.6 MB*. Moscow: National Research University Higher School of Economics.

Greco, Salvatore, Alessio Ishizaka, Menelaos Tasiou, and Gianpiero Torrisi. 2019. On the Methodological Framework of Composite Indices: A Review of the Issues of Weighting, Aggregation, and Robustness. *Social Indicators Research* 141: 61–94. [CrossRef]

Instituto Mexicano para la Competitividad (IMCO). 2023. "Índice de Competitividad Digital Estatal" (State Digital Competitiveness Index). Available online: https://imco.org.mx/indices/indice-de-competitividad-estatal-2022/ (accessed on 13 February 2023).

Jensen, Robert T. 2007. The Digital Provide: Information (Technology), Market Performance and Welfare in the South Indian Fisheries Sector. *Quarterly Journal of Economics* 122: 879–924. [CrossRef]

McKinsey Global Institute (MGI). 2015. Digital America: A Tale of the Haves and Have Mores. Available online: https://www.mckinsey.com/~/media/mckinsey/industries/technology%20media%20and%20telecommunications/high%20tech/our%20insights/digital%20america%20a%20tale%20of%20the%20haves%20and%20have%20mores/mgi%20digital%20america_executive%20summary_december%202015.pdf (accessed on 13 February 2023).

Nardo, Michela, Michaela Saisana, Andrea Saltelli, and Stefano Tarantola. 2005. *Tools for Composite Indicators Building*. Ispra: European Comission, vol. 15, pp. 19–20.

Negroponte, Nicholas. 1995. *Being Digital*. New York: Alfred A. Knopf.

OECD. 2014. *Measuring the Digital Economy: A New Perspective*. Paris: OECD Publishing. Available online: www.oecd.org/sti/measuring-the-digital-economy-9789264221796-en.htm (accessed on 13 February 2023).

Selwyn, Neil. 2004. Reconsidering Political and Popular Understandings of the Digital Divide. *New Media & Society* 6: 341–62. [CrossRef]

Sidorov, Anatoly, and Pavel Senchenko. 2020. Regional Digital Economy: Assessment of Development Levels. *Mathematics* 8: 2143. [CrossRef]

Tikunov, Vladimir S. 1997. *Classifications in Geography: Renaissance or Withering? (The Experience of Formal Classifications)*. Smolensk: Publishing House of SSU. 367p.
World Bank. 2016. Digital Dividends. Available online: https://openknowledge.worldbank.org/bitstream/handle/10986/23347/210671RuSum.pdf (accessed on 13 February 2023).