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QUANTITATIVE EVALUATION OF REGIONAL DIGITAL INEQUALITY AND ITS COMPARISON WITH KEY ECONOMIC AND SOCIAL INDICATORS OF RUSSIAN REGIONS

ABSTRACT

This paper describes the development of a Digital Inequality Index that allows a comprehensive assessment of disparities in digital access and proficiency. The methodology is based on a three-level concept of digital inequality, incorporating assessments of technology access, skills, and real-life application effectiveness. Three groups of statistical indicators are used to access technology, skills, and effectiveness of obtaining results in real life. Through these indicators, the research maps out digital inequality, allowing for a comparative analysis across regions. The validation of the methodology was conducted using the example of the regions of Russia. The findings highlight significant disparities, with infrastructure issues in remote areas, economic constraints in low-income groups, and skill shortages in rural and older populations. To analyze the ratios of the developed integral Digital Inequality Index and other socio-economic indicators of the regions, the authors created two cloud diagrams focusing on the percentage of the population with higher education and the percentage of the urban population. The study emphasizes the urban-rural divide, with urban areas showing lower digital inequality due to better infrastructure and skills. The paper argues for comprehensive regional strategies that combine infrastructure development with skill improvement programs to bridge the digital divide and enhance quality of life. The findings contribute to understanding the multifaceted nature of digital inequality in Russia and provide a foundation for targeted policy interventions.

KEYWORDS: index, digital inequality, Russian regions, digital economy

INTRODUCTION

The rapid advancement of technology began in the last decades of the 20th century and accelerated in the early 21st century with the growth of the Internet. This technological progress has significantly impacted the economy, politics, culture, and society at large. Initially, it was believed that digital technologies would erase boundaries between people, provide access to knowledge in the most remote corners of the Earth, and offer new opportunities for those previously unable to afford quality education. However, it soon became clear that access to technology alone was insufficient, and scientists began to identify emerging issues of technological inequality by the end of the 20th century. Research conducted in the late 1990s revealed that access to high-speed internet was limited by geographic and socio-economic factors. For instance, in the USA and Europe, issues were identified with internet access among low-income populations, rural residents, and individuals with disabilities [*Hoffman*, *Novak*, 1998; *Strover*, 1999]. This resulted in the introduction of the term “digital divide”, which refers to the gap between individuals, households, businesses, and geographic areas at different socio-economic levels regarding their

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ability to access information and communication technologies (ICTs) and use them for various activities[1].

As information technologies became more widespread, the issue of uneven access to them became more pronounced. It was observed that inequality could persist even when practically equal access to technologies was provided. This phenomenon is evident in both high-income [*Peter*, *Valkenburg*, 2006; *Hargittai*, *Hinnant*, 2008] and low-income countries [*Drori*, 2010], as confirmed by reports from the International Telecommunication Union[2].

Studies have also indicated that the usage patterns of the Internet and other digital technologies vary according to age, gender, educational level, and income of the users. For instance, younger individuals, those with higher education, and higher incomes are more likely to use the Internet and other digital technologies compared to older adults, those with less education, and lower incomes. This led to the broader concept of "digital inequality", which encompasses systematic differences between individuals of varying socio-economic status in terms of their access, skills, usage, and outcomes from interacting with digital technologies [*Büchi*, *Hargittai*, 2022]. This concept includes not only the digital divide but also other factors affecting the use of technology by individuals who have formal access to it. Inequality is also manifested in the uneven distribution of Internet skills (such as the ability to search for information) and in the use of the Internet for purposes beyond entertainment or social networking [*Van Deursen*, *Helsper*, 2015].

P. Rydzewski [2025] argues that digital inequality represents a critical challenge in the pursuit of sustainable development of territories, as disparities in access to and proficiency with digital technologies hinder equitable growth, social inclusion, and environmental sustainability.

The mentioned studies on digital inequality have demonstrated that access to and use of digital technologies are characterized by disparities linked to geographical, socio-economic, and cultural factors, which can lead to further issues and the digital isolation of certain population groups.

Contemporary research identifies three levels of digital inequality:

1. The first level is inequality in access to technology, caused by economic or physical constraints, known as the actual digital divide.
2. The second level is inequality in technology usage skills, stemming from variations in digital literacy and education levels.
3. The third level is inequality in the ability to achieve tangible outcomes in real life through technology usage patterns, which can affect employment, education, political participation, and other areas [*Van Dijk*, 2012; *Du* et al., 2021].

In Russia, interest in this topic emerged in the 1990s and has since intensified [*Avraamova*, *Vershinskaya*, 2001; *Gladkova* et al., 2020; *Yudina*, 2020; *Kurilova*, 2025]. The term "digital inequality" entered scientific discourse following an international seminar on "The Challenges of Overcoming 'Digital Inequality' in Russia and CIS countries" held in November 2000 [*Zakharov*, *Sidorova*, 2016]. However, there has been some confusion in aligning the English and Russian terminologies. Most studies on digital inequality in Russian regions primarily approach the subject from a technological perspective, focusing on the gap between those who have and do not have access to digital technologies and analyzing numerous factors influencing this divide. Broadband internet access indicators are frequently examined [*Gruzdeva*, 2020; *Dudin* et al., 2021; *Zemtsov* et al., 2022]. Some researchers go further and analyze the second level [*Kvasnikova* et al., 2020; *Nikolaeva*, *Ivanov*, 2020], or both the first and second levels together [*Grishchenko*, 2020; *Yanovskaya* et al., 2022].

1 OECD, Understanding the Digital Divide (2001). Web resource: http://www.oecd.org/dataoecd/38/57/1888451.pdf (accessed 31.03.2023)

2 Measuring the information society. Geneva: ITU. Web resource: http://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis2011.aspx (accessed 31.03.2023)

Sufficient statistical information is available for assessing the first two levels of inequality. However, it's important to recognize that the methodological approaches for gathering statistical data on the use of ICT in various countries do not fully capture the third level of digital inequality at the regional level. Most existing studies of the third level of digital inequality utilize a sociological approach, yet, currently, there is no universally accepted methodology for assessing the third level of digital inequality.

Geographical studies that encompass a comprehensive assessment of all three levels of digital inequality are still rare. For instance, the work of Spanish researcher D. Gómez [2018] analyzes the three levels of digital divide among the youth in a district of Madrid, while a paper by Russian researchers [*Gladkova* et al., 2019] tests a three-level model for comprehensive analysis of the digital divide in the Republic of Tatarstan. The challenge of such research lies in the difficulty of quantitatively assessing the third level of digital inequality for larger territorial entities in a way that is comparable to the first two levels.

In the study [*Ragnedda*, *Kreitem*, 2018], the authors analyze indicators related to the proliferation and use of the Internet (the first level of digital inequality), the level of digital skills (the second level of digital inequality), and the digital services used by citizens in Eastern EU countries to improve their quality of life (the third level of digital divide). The use of digital services as an indicator for assessing the third level is debatable, but few alternatives have been proposed to date.

Based on the experiences from the abovementioned studies, the authors of this work propose their solution to the issue of combining assessments of all three levels of digital inequality, exemplified by the regions of Russia. The aim of the research is to develop a digital inequality index that allows for a comprehensive assessment of digital inequality at the regional level in Russia and comparing the resulting index with some basic socio-economic indicators of the regions.

RESEARCH MATERIALS AND METHODS

Three groups of statistical indicators were collected to evaluate the three levels of digital inequality across the Russian Federation's subjects. The detailed description of the methodology is provided in [*Chereshnia*, *Gribok*, 2023].

The first level of digital inequality was assessed through the infrastructure of broadband Internet access using indicators of the number of broadband Internet subscribers per 100 people for both fixed (via fixed-line communications such as fiber optic cables, DSL, or cable television) and mobile internet. These indicators reflect the population's access to broadband internet and are markers of a stable telecommunications network's presence. The mobile Internet subscribers' figure also indicates the level of telecommunications infrastructure development, as it demonstrates the widespread availability of mobile networks and internet access through them. These indicators are widely used to assess ICT access inequality both in Russia and globally, succinctly characterizing both economic constraints (the population cannot afford broadband access) and physical limitations (the difficulty of providing broadband access in regions due to their remoteness). These two indicators were aggregated into an "Infrastructure Level" indicator.

The second level of digital inequality was also assessed using indicators published by Rosstat: "Population skills in personal computer use (as a percentage of the total number of people using personal computers): Working with a text editor; Transferring files between the computer and peripheral devices (digital camera, player, mobile phone); Working with electronic spreadsheets" and "Population never using the Internet". These indicators have proven effective in many studies, but they also have their shortcomings. For instance, they become outdated over time as new utilities and programs become necessary for efficient modern system operation. For example, government statistics doesn't assess skills in using mobile devices, conducting secure payments, safely using social networks, working with cryptocurrencies, or artificial intelligence. The “Population never using the Internet” indicator shows individuals who do not use the Internet due to a lack of need (unwillingness to use, no interest), lack of skills for internet use, high connection costs, absence of technical means to connect, and concerns over security and privacy. The initial indicators were aggregated into a “Digital Skills Level” indicator.

The assessment of the third level of digital inequality is a distinct scientific task. While various assessment methods for the first two levels could be adapted for our research, the study of the third level is a new field. This new field lacks established evaluation techniques. It also lacks statistical data available at the sub-national level. For this task, we developed a new method, detailed in the article [*Chereshnya*, *Gribok*, 2022]. It is based on identifying three categories of search queries by regional users in Google, associated with different types of digital technology use and their impact on quality of life. It’s assumed that user search queries reflect their primary Internet usage patterns. People with higher education and income tend to use information technologies for informational, educational, work, and career purposes, while those with lower levels of education and income primarily use applications for entertainment, chatting, social networking, or simple communication [*Zillien*, *Hargittai*, 2009; *Van Deursen*, *Helsper*, 2015; *Tsetsi*, *Reins*, 2017]. Other data support this assumption, showing, for example, that people with higher education levels gain more economic, institutional, and educational benefits from the Internet than those with less education. Building on these findings, we categorized search query patterns into conditionally positive and conditionally negative, based on their impact on the population’s quality of life. The first category included queries related to everyday services and utilities. The second category encompassed queries related to education, science, and technology. The third category comprised queries related to entertainment. A high interest in the first and second categories indicates more effective use of the Internet, whereas utilizing the Internet for entertainment does not contribute to its efficiency. Based on the collected data, indices of search interest for each of the three thematic categories: “Everyday Services and Utilities”, “Education, Science, and Technology”, and “Entertainment” were calculated. Additionally, a composite index “Level of Internet Usage Efficiency” was computed, which, in this study, served as an indicator for assessing the third level of digital inequality. Since the indicators calculated in the previous research were relevant for the pre-pandemic 2019, we decided to continue study with data for the same year. All indicators we used to calculate the comprehensive digital inequality index presented in Table 1.

Table 1. Indicators for Digital Inequality Index

Indicator	Metrics
Level of Infrastructure	Number of broadband internet subscribers per 100 people, units, fixed
	Number of broadband internet subscribers per 100 people, units, mobile
Level of Digital Skills	Skills of the population in using a personal computer (as a percentage of the total population using a personal computer): • Working with a text editor; • Transferring files between a computer and peripheral devices (digital camera, player, mobile phone); • Working with electronic spreadsheets
	Population that never uses the internet, (%)
Level of Internet Usage Efficiency	Search interest in everyday services and utilities
	Search interest in education, science and technology
	Search interest in entertainment

Based on the aggregated indicators we obtained for each level of digital inequality, a comprehensive Digital Inequality Index was calculated using a mathematical modeling technique described in the work of V. S. Tikunov [1997, P. 83–85]. To obtain the indices of Internet usage efficiency by categories, a normalization of the values of the initial indicators was carried out according to formula (1), as detailed in [*Tikunov*, 1997, P. 83–85].

$$\hat{X}_{ij} = \frac{\left| x_{ij} - \overset{o}{x}_j \right|}{\left| \max/\min x_j - \overset{o}{x}_j \right|}, \qquad i=1, 2, 3,\ldots, n; \quad j=1, 2, 3,\ldots, m \qquad (1),$$

where $\overset{0}{x}$ — represents the worst values for each indicator encountered (for instance, the smallest for the metric "Population's skills in using a personal computer" and the largest for the metric "Search interest in entertainment");

max/min x — the values of the indicators most divergent from $\overset{0}{x}$;

n — the number of territorial units — regions of Russia;

m — is the number of indicators used for calculations.

The purpose of this normalization is to convert each indicator into a deviation from a specified best or worst value.

The resulting normalized indicators are confined to a range from 0 to 1 and can be aggregated into a comprehensive composite Digital Inequality Index by calculating a simple average.

RESEARCH RESULTS AND DISCUSSION

Based on the calculated values of each of the three indicators for the subjects of the Russian Federation, we have created maps that visually display the unevenness of the first, second, and third level digital inequality indicators across the territory of Russia. Fig. 1 presents a map based on the "Level of Infrastructure" indicator, which characterizes the digital inequality of the first level.

The level of broadband access development in Russia is, on average, lower than in developed countries. Russia is a vast country with many densely populated cities and sparsely populated regions, complicating the deployment of broadband infrastructure in these areas. Logically, the highest level of digital infrastructure development is noted in Moscow (0.98), followed by the Novosibirsk Region, St. Petersburg, and the Yamalo-Nenets Autonomous District. The lowest level of broadband infrastructure development is observed in the national republics, especially in the North Caucasus — in Ingushetia (0.20) and Dagestan (0.25). This can largely be attributed to the inaccessibility of many settlements, the general level of infrastructure, and the low-income levels of the population.

We should separately note the Republic of Crimea and Sevastopol, where, according to official data, the indicators of internet access are extremely low. However, it can be argued that these do not reflect the real situation since, in 2019, due to sanctions, many services, especially in mobile communications, were accessed by residents through alternative means.

In recent years, Russia has been actively investing in infrastructure, including the development of broadband Internet access. To reduce the regional disparities in broadband access, it is necessary to increase infrastructure investments, improve the regulatory environment, and promote the adoption of new technologies, such as the deployment of 5G networks. It is also important to ensure the availability of broadband internet for residents of sparsely populated regions to provide uniform access to digital technologies across the entire territory of Russia.

Fig. 2 presents a map based on the "Level of Digital Skills" indicator, characterizing the second level of digital inequality.

Fig. 1. The indicator "Infrastructure level", which characterizes the digital inequality of the first level, 2019

Fig. 2. The indicator "Digital skills level", which characterizes the digital inequality of the first level, 2019

According to our skills assessment, the Chukotka Autonomous Okrug has the highest level of computer literacy among all the regions with a score of 0.84. Following this region are Moscow (0.82) and the Yamalo-Nenets Autonomous Okrug (0.74). On the other hand, the Novgorod Region has the lowest score among the regions at 0.15, characterized by the population's low skills in personal computer use and a high proportion of people who have never used the internet (as much as 20 %). Other regions with very low scores include the Ryazan Region (0.17), the Chechen Republic (0.18), and the Ivanovo Region (0.26). The assessment reveals significant variation in the level of computer literacy across different Russian regions, which could impact the development of the digital economy in these areas. The low level of computer literacy in Russian regions can be due to several reasons:

1. Insufficient development of infrastructure, limits access to technologies for many individuals.
2. Limited access to training and education in computer literacy.
3. A lack of motivation among the population to learn computer literacy.
4. Low-income levels.
5. The age factor: research indicates that computer literacy levels among the elderly are lower, which may be linked to their reluctance to learn new technologies or difficulties in using them.

Regions with high levels of computer literacy may have greater opportunities to utilize digital technologies in various sectors, including the economy, healthcare, and education. Conversely, regions with low computer literacy, such as the Novgorod Region, may experience limited access to digital services and opportunities, potentially leading to a decline in their economic and social development. Enhancing computer literacy and the accessibility of digital technologies in such regions could be a crucial step towards reducing digital inequality and ensuring equal opportunities for all citizens of Russia.

Geographical patterns are also evident in the effectiveness of internet usage by populations. Regions of the North Caucasus are particularly notable for their lowest levels of internet usage efficiency. Search queries in this region primarily gravitate towards entertainment, indirectly indicating that the internet is seldom used for economically and socially beneficial activities. The highest levels of internet usage efficiency have been identified in Tatarstan and Yakutia, as well as in Moscow and St. Petersburg. Additionally, the regions of Siberia tend to show relatively low internet usage efficiency. Here, users generally do not exhibit high interest in education and science topics, nor do they demonstrate high levels of online service usage, with entertainment searches being above average. The Far Eastern regions display the greatest diversity in the comprehensive index obtained. Some areas, like the Jewish Autonomous Region, have very low internet usage efficiency, while others, like Yakutia, have very high efficiency. The Urals and Central Russia regions show high internet usage efficiency. Here, the population frequently searches for useful services and information for education and science, with the Kurgan Region being the sole exception.

The comprehensive assessment of digital inequality (Fig. 4) shows that the lowest levels of digital inequality are observed in Moscow and St. Petersburg, the Yamalo-Nenets Autonomous Okrug, the Republic of Tatarstan, and the Moscow Region. The situation with digital inequality is worst in the Caucasus regions, including the Karachay-Cherkess Republic, the Republic of Dagestan, the Chechen Republic, and the Republic of Ingushetia. These regions lag behind in the entire spectrum of indicators. Some regions of Siberia and the Far East also stand out for their high level of inequality. The Ural and North-West regions exhibit relatively low levels of digital inequality. Notably, except for the Moscow Region, Central Russia generally has a higher level of inequality.

Fig. 3. The indicator "Level of efficiency of Internet use", which characterizes the digital inequality of the third level, 2019

Fig. 4. The Digital Inequality Level, 2019

Besides using maps to show data, we can also clearly demonstrate the spread of regions according to the Digital Inequality Index with scatter plots. This type of visualization also allows us to compare this index with other statistical measures of Russian regions and to estimate its connections with various socio-economic data at a regional level. The convenience of such graphs is that they can be used to compare the distribution of several different indicators: values along the axes, the size and color of the circles.

We created two scatter plots. On the vertical axis of both is the value of the digital inequality index we calculated, which ranges from 0 to 1. The closer to zero, the more pronounced the digital inequality. Each dot represents one region of Russia (the data does not include the Republic of Crimea and Sevastopol because the index for these regions was not calculated due to the lack of data for the third level of digital inequality). The size of the dots is proportional to the population size of the regions, and the color represents the average income, adjusted for purchasing power parity.

In the scatter plot shown in Fig. 5, the distribution of regions along the horizontal axis corresponds to the percentage of the population aged 15 and older with higher education. This indicator is derived from the results of the latest population census in Russia, conducted in 2021. As mentioned earlier, the level of education of users is directly linked to the second and third levels of digital inequality. The cloud of points is elongated from the bottom left corner to the top right, indicating, as expected, a general positive correlation between the indicators on the vertical and horizontal axes.

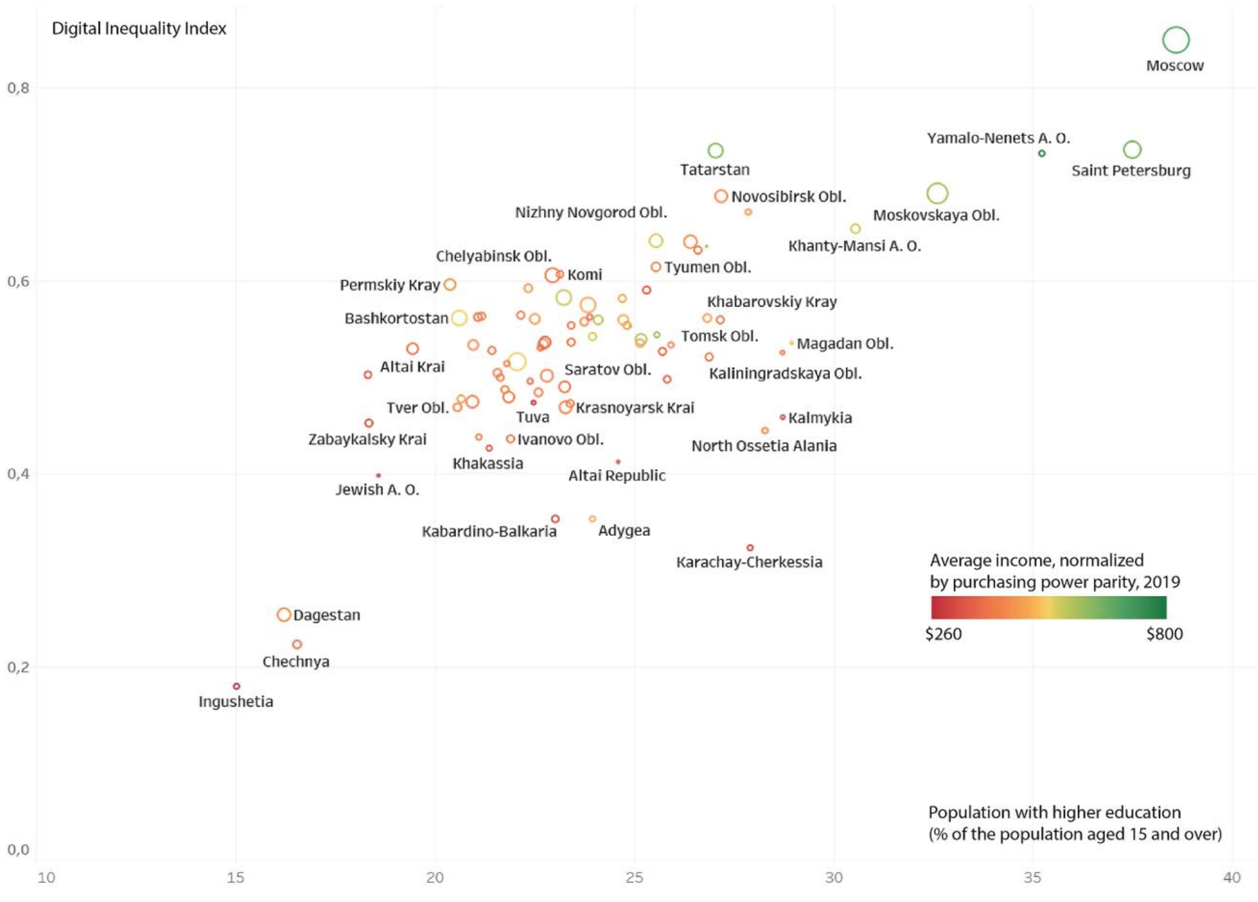

Fig. 5. The relationship between the digital inequality index and the proportion of the population with higher education in Russian regions

In the bottom left corner of the diagram, set apart from the other points, are the Republics of Ingushetia, Dagestan, and Chechnya, which show a high level of digital inequality and low average income, with a relatively small percentage of the population holding higher education degrees. In the top right corner, Moscow and St. Petersburg, along with the Yamalo-Nenets Autonomous Okrug, have high income levels and low levels of digital inequality, as well as a high percentage of the population with higher education.

The central part of the diagram is oval-shaped. Along the bottom right edge, mainly the republics of the North Caucasus are located: Karachay-Cherkessia, Adygea, Kabardino-Balkaria, North Ossetia, as well as the republics of Kalmykia and Altai. Despite a relatively high proportion of the population with higher education, these regions have a worse digital inequality situation than most others. The authors have reasons to suggest that the quality of higher education obtained in these regions may be lower, or there could be an artificial inflation of the proportion of the population with higher education (for example, through diploma falsification). In addition, it is noted that these regions face difficulties in accessing digital infrastructure and have low user skills.

Regions with cities with a population of over one million are located along the top right edge of the scatter plot. These include Perm Krai, Chelyabinsk Oblast, Nizhny Novgorod Oblast, the Republic of Tatarstan, among others. Despite average levels of higher education among the population, these regions have a relatively low level of digital inequality. Residents of large cities have better access to digital infrastructure, which reduces the level of digital inequality. This highlights the importance of infrastructure development to improve access and use of digital technologies.

To assess the relationship between the level of digital inequality and the level of urbanization of regions, we constructed a second scatter plot, where the values on the horizontal axis correspond to the proportion of urban population in the regions of Russia. The diagram is shown in Fig. 6. It is similar in shape to the previous one and also has an elongated form. There is a tendency for regions with a high proportion of urban population, such as Moscow and St. Petersburg, to have lower levels of digital inequality. In the bottom right corner are regions with a smaller proportion of urban population, such as the republics of the North Caucasus, as well as predominantly rural republics like Kalmykia, Altai, and Tuva, indicating a higher level of digital inequality. The distribution of regions on the diagram does not show a clear correlation between the level of urbanization and digital inequality, but it can be noted that more urbanized regions tend to have a lower level of digital inequality.

Additionally, it's observed that in both scatter plots, the upper part (i.e., regions with a low level of digital inequality) contains more regions with high incomes compared to the lower part. Overall, the maps and diagrams we've constructed show that our developed comprehensive digital inequality index for Russian regions is closely related to other basic socio-economic and demographic indicators of the regions and complements existing theories about the significant territorial heterogeneity of the country. Among these is the division of Russian space into four conditional internal "states" described by N.V. Zubarevich (2012), which includes the most modernized "country of big cities", the working "country of industrial cities", the peripheral "rural Russia", as well as the republics of the North Caucasus and southern Siberia (Altai and Tuva), which do not conform to the center-periphery model and are significantly different from other regions.

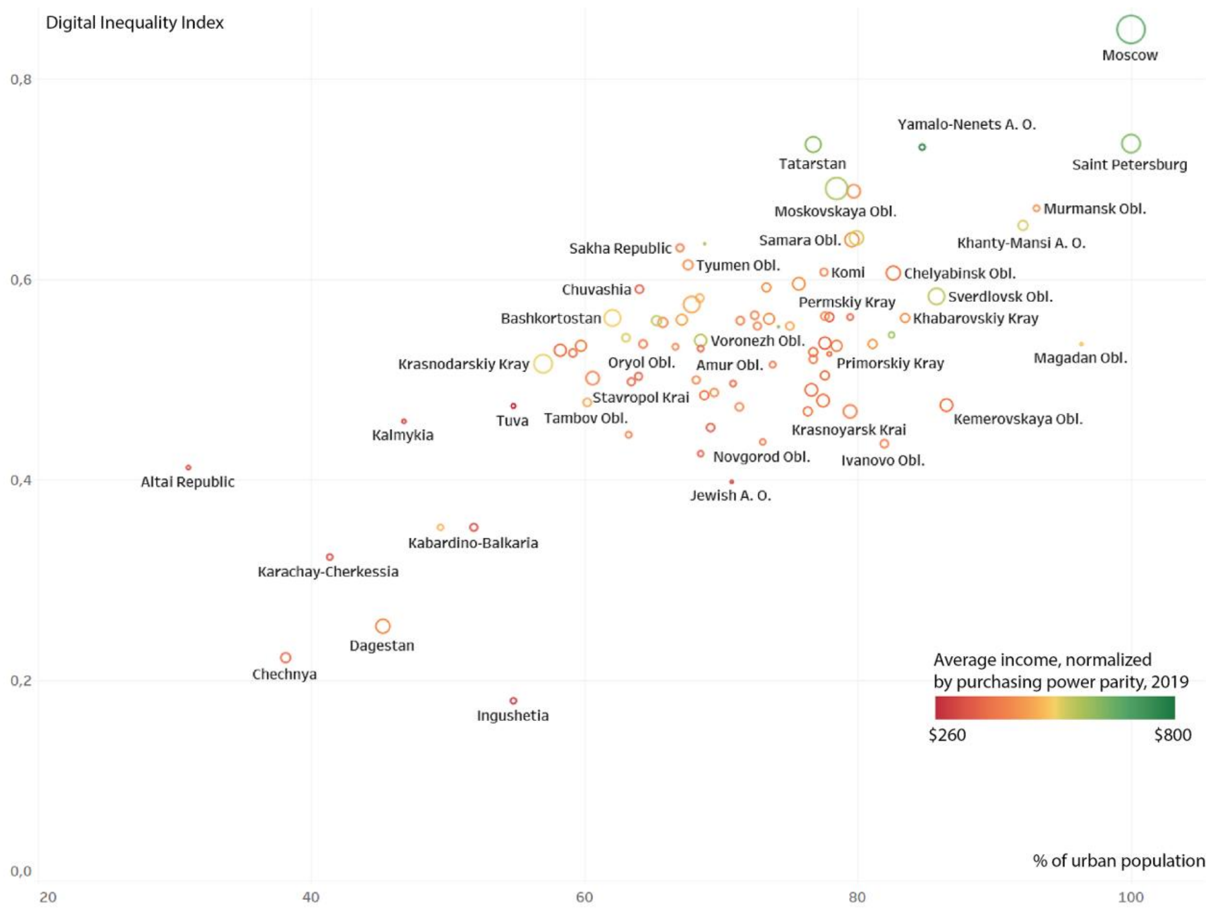

Fig. 6. The relationship between the digital inequality index and the proportion of urban population in Russian regions

CONCLUSIONS

The study shows that the situation in Russian regions varies significantly across all levels of digital inequality. There are infrastructure access issues in remote territories, economic limitations among less affluent population segments, a lack of skills among rural and older age groups, and insufficient technology usage efficiency. Some regions, like the Chukotka Autonomous Okrug, demonstrate high computer skill levels despite low infrastructure development. Here, reducing the cost of communication services and developing next-generation networks would be effective. Conversely, regions like those in the North Caucasus lag in all digital inequality indicators: poor infrastructure development, low computer literacy, and the lowest effectiveness in using technology to enhance life quality. This situation creates a vicious cycle: a lack of access leads to an inability to develop computer skills, which in turn leads to a lack of understanding of effective strategies for implementing technology in everyday life. In such regions, investments in digital infrastructure alone will not suffice and will not yield the desired result. As seen in other countries, populations with low computer literacy who gain access to technologies may even experience a decrease in quality of life due to increased risks of fraud, loss of important personal data, and insurmountable barriers when mandatory electronic procedures are introduced (e. g., obtaining vaccination certificates), preventing them from exercising their rights. Moreover, new technological entertainments that require much less computer skill and effort can diminish opportunities for effective work and learning. Therefore, the digitalization strategy for such regions must include programs to improve computer skills and enhance the digital competencies of the population, particularly in terms of safety and effective use.

Some factors that may influence digital inequality in Russia include:

1. Geographical location. Populated areas in remote territories of Russia may have limited access to broadband internet due to insufficient infrastructure.
2. Socio-economic status. Poor and less affluent population segments may have restricted access to digital technologies due to the inability to afford necessary equipment or pay for internet access services.
3. Education. Individuals with lower education levels may face difficulties in using digital technologies.
4. Age. Older adults may have limited access to digital technologies due to low levels of computer and technological literacy.
5. Level of urbanization. In urban areas (especially in the largest cities), the population has more opportunities to use digital technologies and more developed relevant skills than in rural areas.

To reduce digital inequality in Russia, it is necessary to improve the accessibility of broadband internet, especially for rural populations and those in remote territories, and to develop support programs for less affluent population segments. It is also crucial to increase the level of computer and technological literacy across all age groups, including in rural regions.

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