





Digitalization as a Factor of the Sustainable Development of Regional Economic Systems: The Case of the Urals Regions

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Abstract: The article focuses on three the three concepts that make up its name: digital technology, territory and sustainable development. Sustainable development requires progress on these three directions, otherwise it turns into stagnation, or false development because of its exclusivity. Territories of the Russian Federation differ in disparities of economic development, living conditions, natural and climatic factors. Each region is unique, so socio-economic changes in each subject require an individual approach. Theoretical and methodological basis of the paper are the results of foreign and Russian researchers on the problems of sustainable and balanced regional development and digitalization processes. The conclusions are based on the results of the cluster analysis of indicators of regional activity of the Ural Federal District, the identification of the causes influencing the differentiation, and the direction to overcome significant differences in regional development. The authors proposed to create a single digital economic space for the district and the country to expand innovative inter-regional integration. It is noted that digitalization not only contributes to economic growth and competitiveness of enterprises, integration of national and regional space, diversification of production structure, but also helps to stimulate social integration and environmental protection, thereby improving the quality of life of present and future generations.


1 INTRODUCTION


The sustainable development agenda requires the design, implementation, monitoring and evaluation of public policies that simultaneously consider economic, social and environmental dimensions. Territory at its different scales (global, regional, national and subnational) is a key element in shaping a new consensus and policy because it emphasizes the diversity of contexts and actors and therefore the diversity of strategies needed to respond adequately to the specifics of situations and problems. Sustainable development implies institutional development, precise rules of the game that bring together all participants, and broad encouragement of entrepreneurial activity. Freedom from the economic point of view must be seen as fundamental to achieve


this goal, provided that the State refrains from intervening in the economy, except to create equal opportunities. As far as productive forces are concerned, they should be concentrated in those sectors of the economy which have a comparative advantage.


The theoretical basis of the article concludes the provisions of regional economics on the structure and evolution of regional economic systems, the concept of sustainable development. The methodological tools of the authors include methods of system and econometric analysis.

The object of the study is regional economic systems of the territories of the Ural Federal District. The processes of development and digitalization of these systems are the subject of the study. The

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analysis is carried out on the primary indicators of official statistics for 2019-2021.

The aim of the paper is to develop the concept of using integrated mechanisms to achieve sustainable regional development, stimulating the processes of economic and social change in five directions: economic, spatial, social, environmental and digital.

To achieve the goal, the study solved the following tasks: formulate the author's attitude to the concept of sustainable development, determine the content of the impact of digitalization on various components of the regional economic system, conduct a cluster analysis of regional activity indicators of the Ural Federal District and identify the causes of differentiation, offer recommendations to improve regional policy for sustainable development through the effective involvement of digitalization potential.

The results of the research are to provide a tool for analyzing the policy of territorial development, which will allow to identify problems and lay the foundation for the construction of an ecosystem of territorial development policy. The proposed integrated regional mechanism of sustainable development can find application at different levels of territorial management.

2 THEORETICAL FOUNDATIONS OF SUSTAINABLE DEVELOPMENT AND DIGITALIZATION OF REGIONS

Currently, there are multiple definitions of sustainable development, reflecting the complexity of the concept, including the socio-economic and environmental problems of regional development.

The concept of sustainable development is based on the Brundtland Commission Report, which describes it as «a process capable of meeting the needs of present generations without compromising the ability of future generations to meet their own needs» (Brundtland, 1989). From this perspective, economic development and natural resource management are inextricably linked in time and space. Commonly this concept is used with a focus on environmental aspects, but it is also based on other components.

A number of authors (Apostu et al., 2022; Youssef et al., 2018; Castaño et al., 2016) consider the

sustainability of territories as "a socio-economic ecosystem capable of responding to changes in the internal and external environment, ensuring the continuous growth of its parameters and timely prevention of the negative effects of economic activity in the future.

In the works (Clercq & Voronov, 2011; Koval et al., 2023; Kirillova & Danilenko, 2021; Dhahri & Omri, 2018; Bogdanov, 2003; Glumov, 2018) studied and described "the relationship between the stability of systems of different levels", it is proved that "the stability of the system to a greater extent determines the stability of structural relationships than its elements".

According to M.V. Vladyka, T.V. Serebrov, V.I. Tikunov (2022), "the regional mechanism of sustainable development can be considered as a set of actions, the implementation of which will bring socio-economic progress to a new level".

Sustainable development implies institutional development, precise rules of the game uniting all participants, and broad encouragement of entrepreneurial activity. Freedom from an economic point of view must be seen as fundamental to this goal, provided that the state refrains from interfering in the economy, except to create equal opportunities. As for productive forces, they should be concentrated in those sectors of the economy that have a comparative advantage. In other words, the sustainable development of the territory is understood as a process and implies changes in many different areas: production systems, consumption patterns, labor market, territorial governance and institutionalism (Filippi et al., 2006; Blizkiy et al., 2020; Rakmeeva, 2018).

The complexity and multidimensionality of the concept of sustainable development requires taking into account a variety of factors affecting this process. From the position of the factor approach, the key factors of socio-economic development of the region are called foreign economic activity (Charushin et al., 2019), a set of objective and subjective factors (Kuznetsova, 2014) and others.

A number of authors refer to such factors as the goals and instruments of monetary policy, noting that "the interregional differentiation of inflation rates, typical for the country, under the conditions of the policy pursued has become even more relevant, since the chosen strategy has a different impact on the sustainability of economic development of regions with different sectoral specificity" and creates obstacles to sustainable economic development of the industrial region (Kuklinova & Ilyashenko, 2022).

In the XXI century digitalization has acquired the status of one of the leading factors of sustainable development of the territory.

The impact of digital technology on the sustainable development of territories was considered in the works (Babkin, 2021; Dobrohotov, 2020; Zubarev et al., 2021; Antipin & Ivanova, 2020). The experts note the key role of digital and information and communication technologies in ensuring the sustainability of modern patterns of production and economic systems (Geissdoerfer et al., 2017; Huggins and Thompson, 2013; Griggs et al., 2014; Samuenko, 2021).

In our writings earlier we have noted the necessity of mastering end-to-end digital competencies by modern specialists in all sectors to ensure the competitive position of the economic system (Blizkiy et al., 2020). Digitalization is now considered a key tool in the transition to a new, more inclusive and sustainable model of development.

It is necessary to distinguish between the concepts of informatization and digitalization. The first implies the inclusion of information and communication technologies in existing production processes and social relations for the purpose of automation. The second means the restructuring of algorithms of economic processes, a radical transformation of social relations on the basis of digital technology, often with the replacement of human resources by artificial intelligence.

To summarize, we define five basic components of the regional economic system, the development of which determines the sustainable development of the territory: economic, social, environmental, information and communication and digital.

However, Russia's regions still face a number of structural problems that hinder the effective implementation of digital technologies. Sustainable development of the regions will depend on the ability to digitalize public administration, the ability of enterprises and organizations to incorporate software into the core of business, create new digital platforms within their usual capabilities, or transform production chains into digitally enabled ecosystems, with interconnected services that meet a variety of cross-sectoral user needs for an integrated experience. The last could allow the creation of smart clusters with local small and medium-sized enterprises that provide a variety of services at different stages of the chain. This productive transformation will have positive consequences at both national and local levels.

3 MATERIALS AND METHODS

The method of cluster analysis (Ward, 1963) was used to estimate the impact of digital technology on the level of economic development of the UrFO macroregion. Cluster analysis is a set of multidimensional methods used to classify indicators into homogeneous groups. Given a set of indicators of digital technology implementation in the region (of N elements), characterized by information from n variables X_j , ($j = 1, 2, \dots, n$), we set ourselves the task to be able to classify them so that the indices belonging to the group (cluster) should be as similar to each other, while different groups should be as unlike each other as possible.

The whole process can be structured according to the following scheme:

- the first step is to compile a set of N indicators of digital adoption in the region, coded with a set of n variables (a data set of N indicators and n variables);
- establish a similarity criterion to be able to define a similarity matrix that allows us to relate the similarity of individuals to each other (a matrix of N indicators * n variables);
- choose a classification algorithm to determine the group structure of individuals;
- indicate this structure using a tree diagram.

We calculate the level of economic development according to the methodology proposed in (Tretyakova and Osipova, 2018), which includes economic, social and environmental indicators, indicators of information and communication and digital technologies.

$$I_{sdj} = \sum_{i=1}^n \frac{X_{sti}}{n} \quad (1)$$

Where I_{sdj} is the group index of sustainable development for the j -th component (economic, environmental, social, information and communication, digital);

X_{sti} - standardized values of the i -th indicator, calculated as the ratio of the actual and the reference (maximum or minimum) values of this indicator among the areas under consideration;

n - number of indicators used for the assessment of this component.

The materials of the study consisted of data from the Federal State Statistics Service for 2019-2021 for the following indicators:

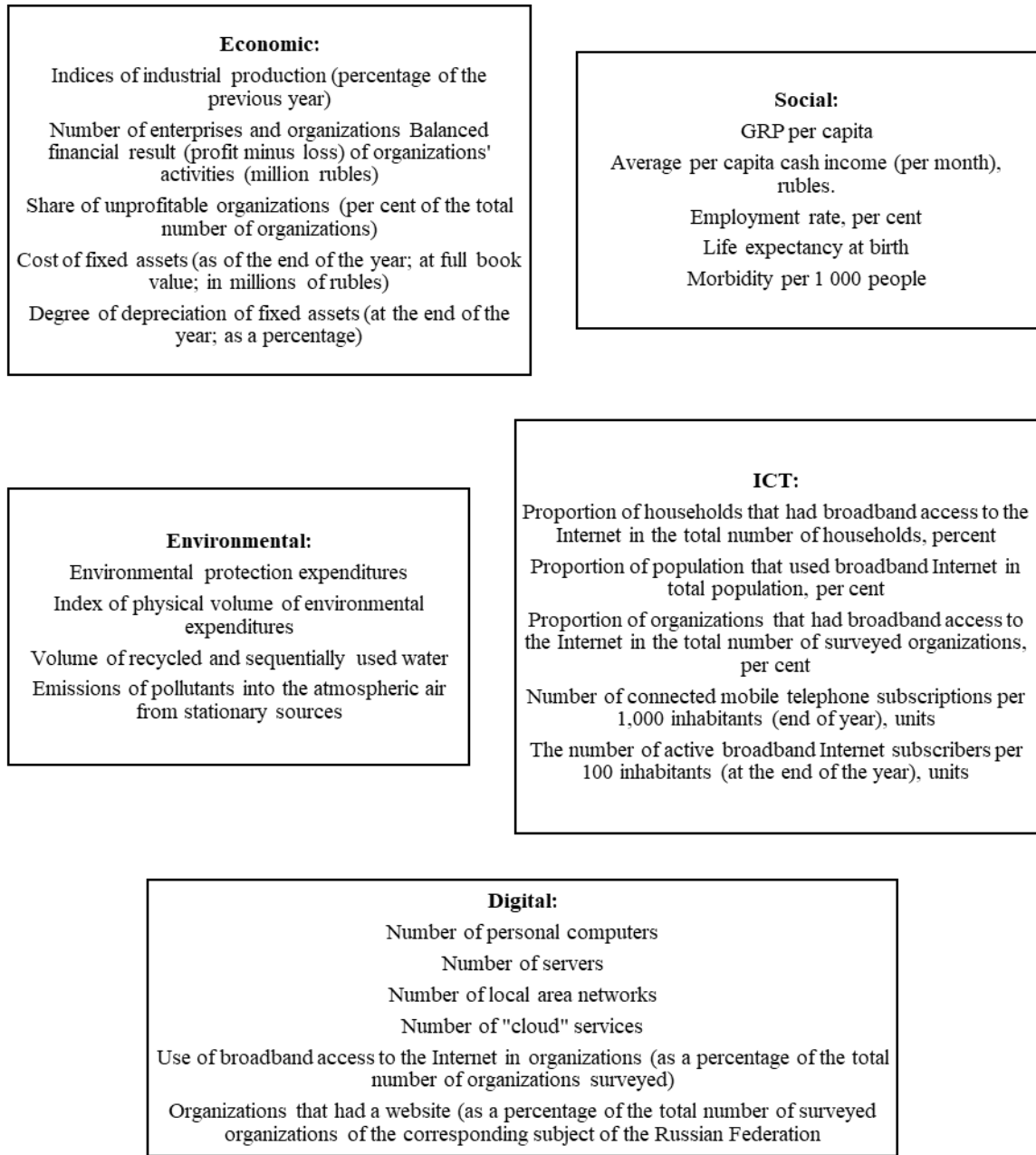


Figure 1: Initial indicators for calculating the assessment of the level of sustainable development in the region.

The final comprehensive assessment of the level of sustainable development in the region is determined by the formula:

$$I_{sd} = \sqrt[5]{\int_{j=1}^5 I_{sdj}} \quad (2)$$

where I_{sd} is the integral static index of sustainable development of the region.

Two groups of regions are distinguished, with a high level of sustainable development (indicators range from 0.5 to 1.0) and low, requiring the elaboration of management decisions in order to increase the level of economic and social development of the region (index value below 0.5).

4 RESULTS AND DISCUSSION

The main peculiarity of the development of Russian regions is the need to comprehensively consider regional differences not only in socio-economic development, but also in the approach to the use of natural resources, historically developed in this territory.

The Ural region is one of the richest mineral regions of Russia. In the north of the region, the Khanty-Mansi Autonomous Okrug-Yugra and YNAO have developed extractive industries, the Sverdlovsk and Tyumen regions are characterized by the development of manufacturing industries, and the industry of the Kurgan and Chelyabinsk regions is a multifunctional complex with a wide range of products.

According to Rosstat, the Sverdlovsk and Chelyabinsk regions, as well as the Khanty-Mansi Autonomous Okrug - Yugra and YNAO are characterized by a high subindex of economic development, primarily due to high growth rates of industrial production in the extractive and manufacturing industries. The economic development of Kurgan region lags behind the average indicators for Russian regions, although in 2021 there was a positive dynamics of industrial production (+5%), the share of profitable enterprises increased (+2.6%).

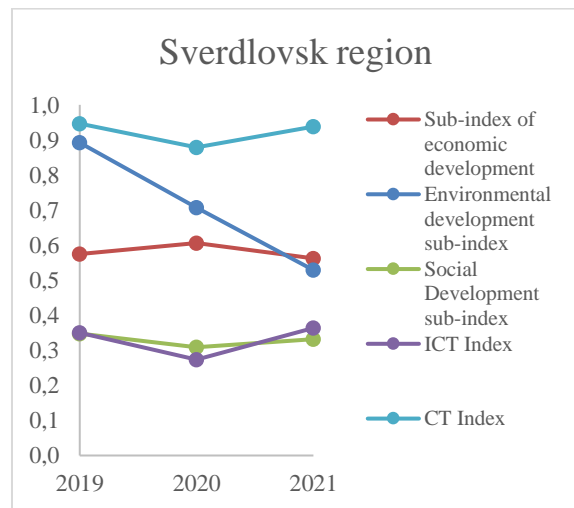
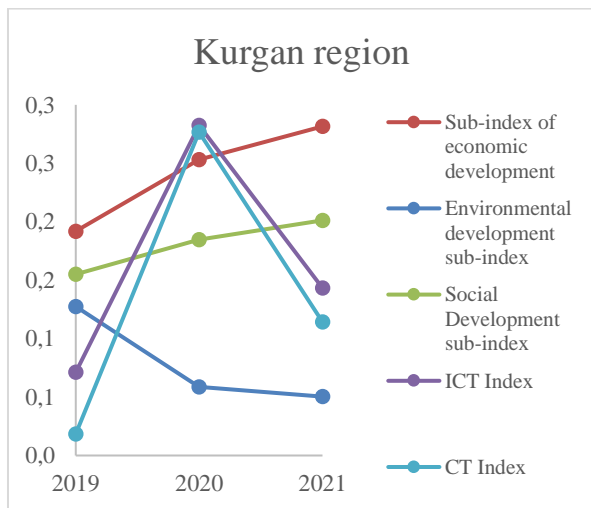
The data in Fig. 2 show that the regions that make up the Ural Federal District differ in the indicators of sustainable development.

The assessment of social development indicators reveals an uneven structure of the Ural Federal District regions, from quite stable KhMAO and YNAO to regions with low social sustainability (Kurgan and Chelyabinsk oblasts). There is an imbalance in health care, education, public safety, more "high income" regions in comparison with subsidized regions have the opportunity to increase spending on significant investment and infrastructure projects. Increased awareness of the importance of environmental and social sustainability, stronger environmental and social protection institutions and regulations can help prevent and mitigate the adverse effects of new projects in these areas.

Since sustainable development is a multidimensional concept, in the course of our research process we analyzed 26 indicators, of which 5 relate to the social subsystem and its relationship with the other subsystems.

In accordance with the indicators described above, we note that there is a significant impact of social development indicators on the overall index of sustainable development of the regions (Table 1). Among the considered indicators for the regions for three years 18 observations were made, since the data do not have a normal distribution, we use non-parametric Spearman correlation coefficient.

Point out the strong correlation between the social development subindex and the ICT index (Fig. 3).



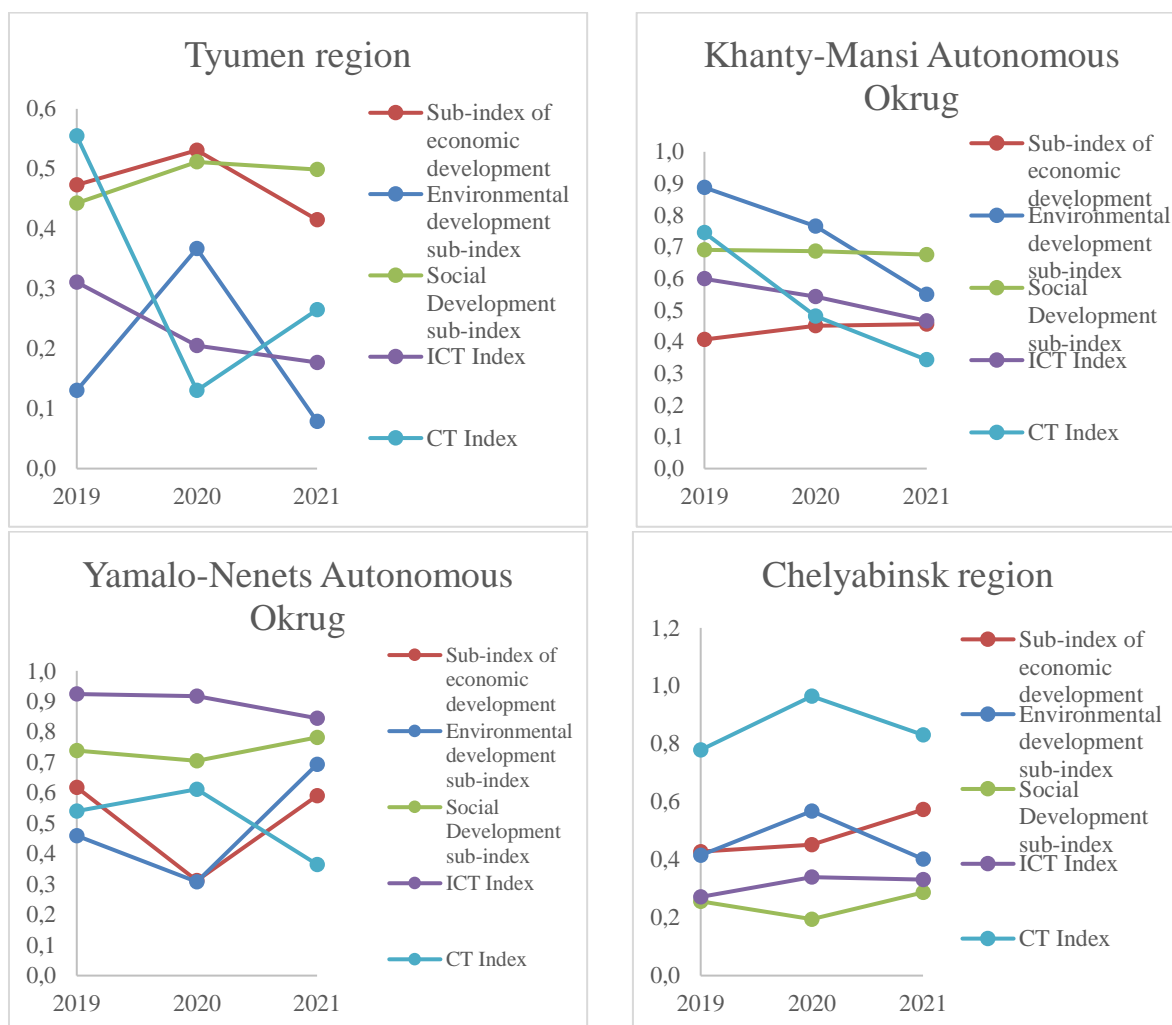


Figure 2: Regions that make up the Ural Federal District differ in the indicators of sustainable development.

Table 1: Spearman's rank correlation coefficient.

	Economic development subindex	Environmental development subindex	Social development subindex	ICT index	Digital Economy and Society Index
Economic development subindex	1	0,545924	0,395253	0,391125	0,477812
Environmental development subindex	0,545924	1	0,401445	0,578947	0,624355
Social development subindex	0,395253	0,401445	1	0,74613	-0,023736
ICT index	0,391125	0,578947	0,74613	1	0,393189
Digital Economy and Society Index	0,477812	0,624355	-0,023736	0,393189	1

Note: Significant correlation coefficients at 18 observations and a significance level of 0.05 are highlighted in yellow.

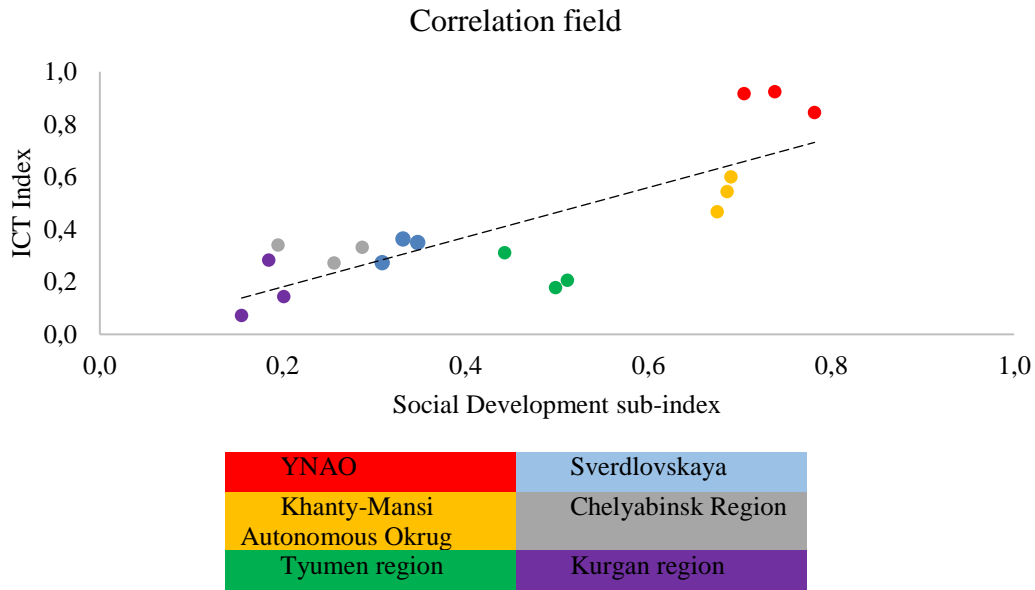


Figure 3: Dependence of social development subindex and ICT index

Information and communication technologies help accelerate the achievement of the Sustainable Development Goals. However, digitalization is not without risks and detrimental effects on the environment. On the one hand, the growing demand of people and businesses for high-speed, high-bandwidth communications for computing, processing and data transmission requires a constant deployment of network infrastructure, production of equipment and hardware devices, and data centers. They in turn are very intensive in energy

consumption, which has a negative impact on greenhouse gas emissions.

In general, the development of digital technologies on the scale of the Russian economy should be characterized as niche, which means that certain segments are forming where the positions of domestic technologies in the domestic market are steadily strengthening, including through the export of infocommunication services. First of all, it concerns the replacement of foreign software with domestic developments.

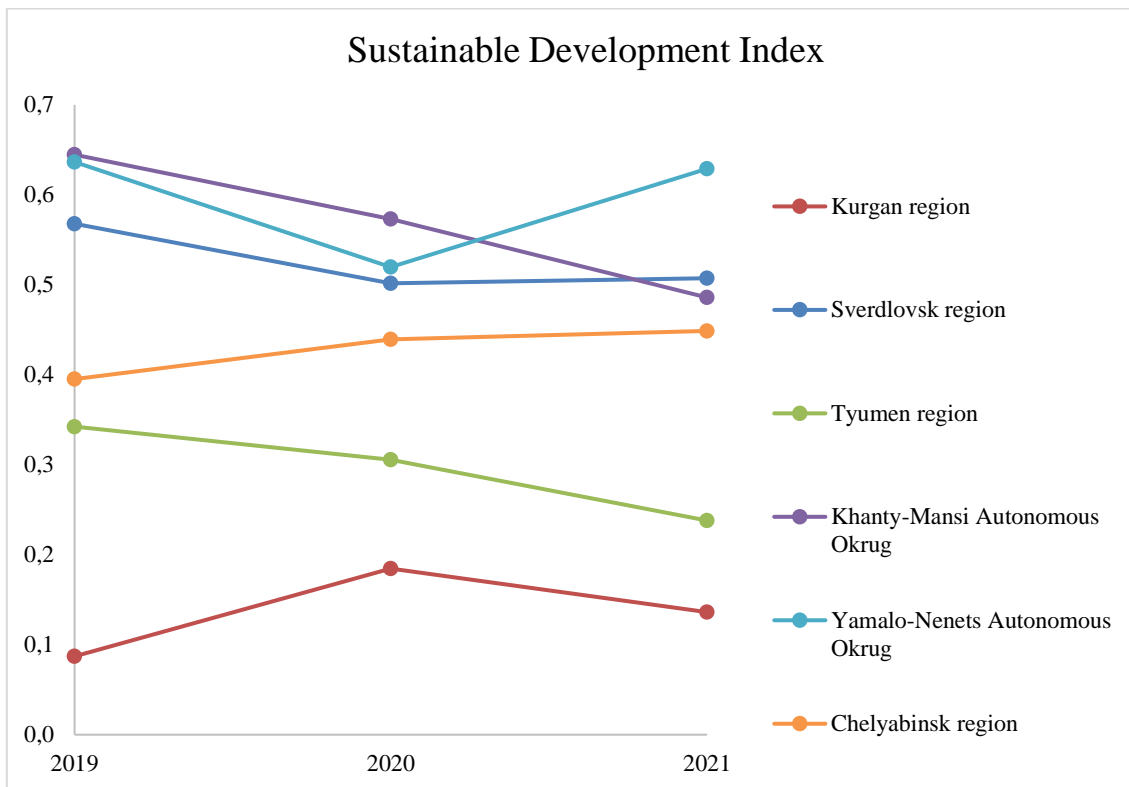


Figure 4: The dynamics of the index of sustainable development of the regions of the Ural Federal District.

These diagrams (fig. 4) show division of the regions into two large groups: with a high level of sustainable development (KhMAO-Yugra, YNAO, Sverdlovsk region) and a low level of sustainable development (Kurgan, Tyumen and Chelyabinsk regions).

To establish whether the results obtained are significant and consistent, it is necessary to find out whether the percentile values found for the four dimensions of the index are representative when using statistical tools. For this purpose, the statistical program SPSS was used and, in particular, graphs were plotted using the tree clustering method (fig. 5, 6). The Euclidean distance square was used as a measure of proximity between objects, and the clustering method was the Ward's method.

The first dendrogram, based on 2019 data, shows a cluster of "lagging" regions (Kurgan, Tyumen and Chelyabinsk regions), and a cluster of "leading" regions (YNAO, KhNAO and Sverdlovsk region). On the dendrograms based on 2020 and 2021 data, the Chelyabinsk region becomes closer to the Sverdlovsk region and joins the "leading" cluster. The same is observed on the diagram of our proposed index of sustainable development.

The cluster analysis by the K-means method confirms our earlier conclusions about the two clusters of sustainable development, and shows the main factors that influenced the level of development of the region.

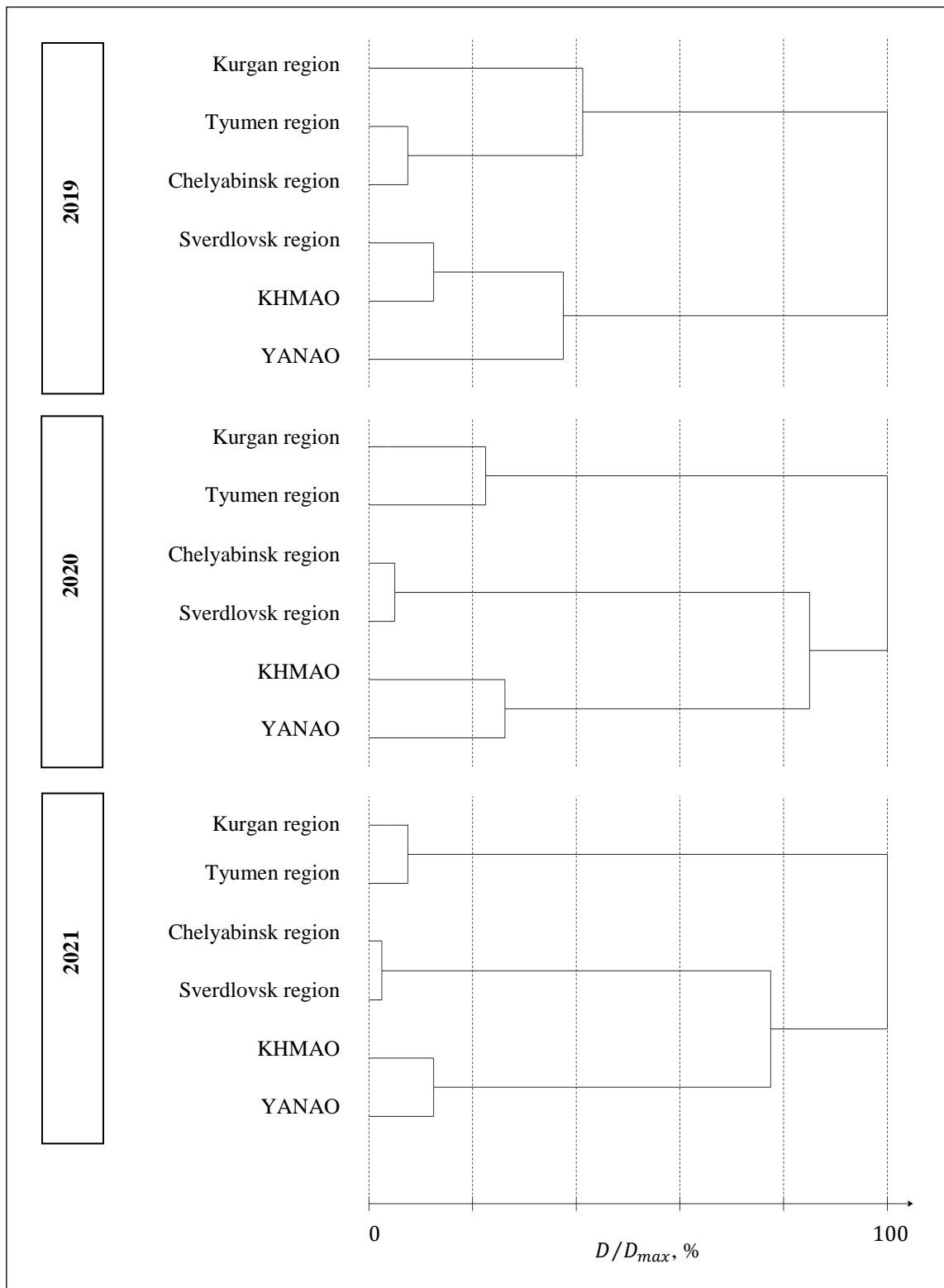


Figure 5: Tree clustering.

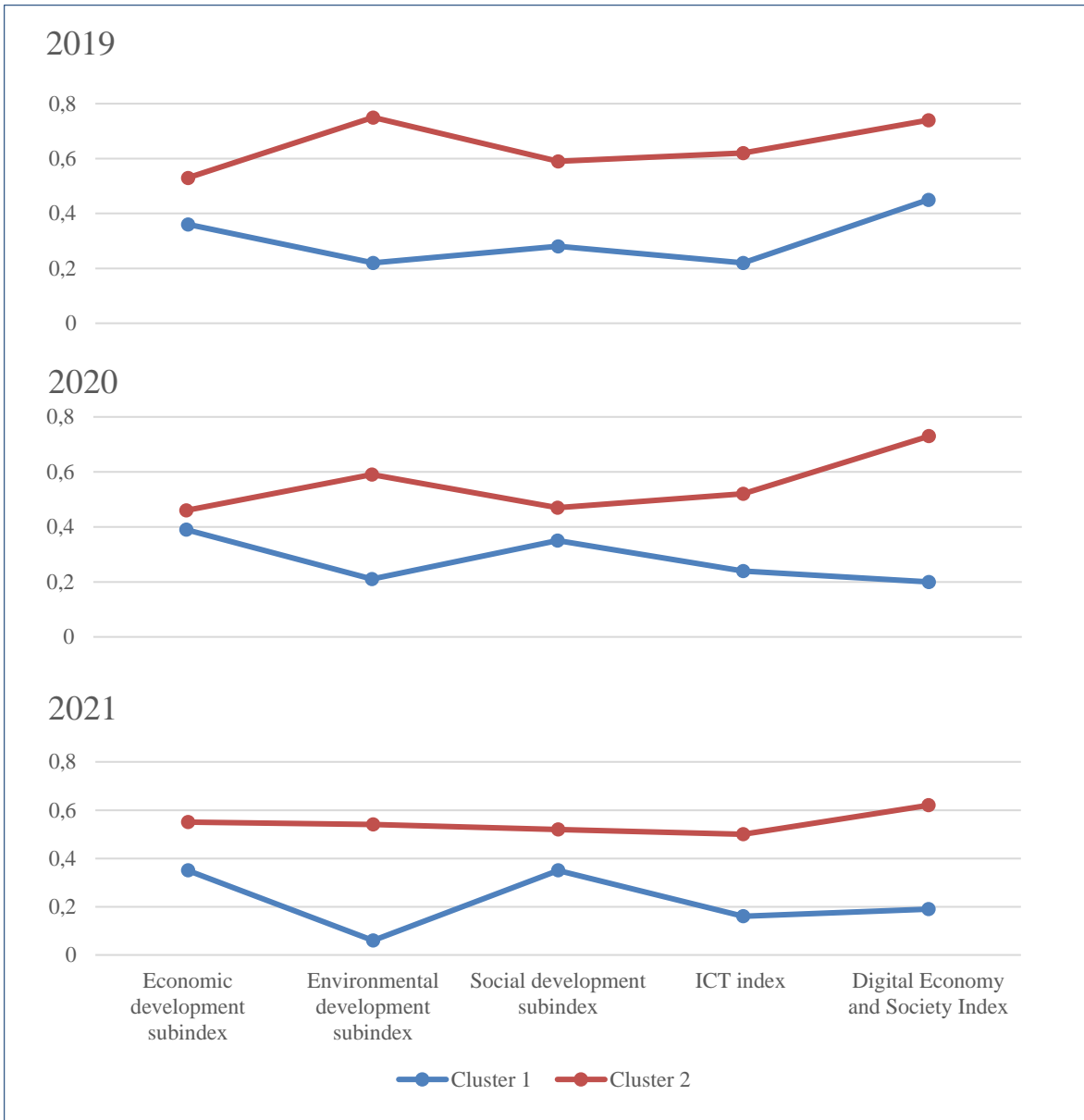


Figure 6: K-means cluster analysis.

The cluster analysis by the k-means method confirms the results of the tree clustering analysis: two clusters can be distinguished among the regions of the UrFO: "leading" and "lagging behind", according to a set of socio-economic and environmental indicators. The Chelyabinsk region, located in the first cluster in 2019, moved to the second cluster in 2020 and 2021. Note that the difference between the clusters is most significant in terms of the CT index, the subindex of environmental development and the ICT index. The difference

between the clusters in economic and social development subindexes is not so significant. This can be interpreted as a difference in the industrial development of the Urals Federal District. Thus, the oil-producing Khanty-Mansi Autonomous Okrug and the gas-producing Yamalo-Nenets Autonomous Okrug showed rather high indicators of sustainable development throughout the entire analyzed period. Industrial regions, where the leading industry was metallurgy and machine building (Sverdlovsk and Chelyabinsk oblasts) are characterized by differently

directed values and are in different clusters (Akberdina et al., 2023; Ilukhin and Ilukhina, 2021). Kurgan region, whose economy has a significant share of agriculture occupies the last place in the ranking. The results of the cluster analysis by the Wards method and the k-means method are consistent with the results of the calculation of sustainable development indices according to our proposed methodology.

In this situation, an in-depth analysis of the individual characteristics of the region will identify important positions where major work should begin to balance and increase the level of sustainable development of the region.

5 CONCLUSION

To summarize, it can be noted that the level of sustainable development of the regions of the Ural Federal District is a very disparate and heterogeneous structure with a developed spatial segmentation from north to south and from east to west, where KhMAO-Yugra, YNAO and Sverdlovsk region in this order are the autonomies with the highest index of sustainable development. The Kurgan, Tyumen and Chelyabinsk regions are in the opposite situation.

The Yamalo-Nenets Autonomous Okrug had the highest indicator in the institutional dimension in 2021 and the Kurgan Oblast had the lowest indicator. Khanty-Mansi Autonomous Okrug - Yugra holds a stable position in the field of production and economic structure compatible with sustainability (economic aspect), and Kurgan region ranks last in this aspect of sustainable development.

The authors propose to create a single digital economic space for the district and the country in order to expand innovation and digital interregional integration. This will intensify the development of other subsystems of regional economic systems and smooth the differentiation of territories. The development of an effective program to create a single digital space of the macro-region may be the subject of future research.

Finally, the created integral static index of the region's sustainable development is an effective tool to analyze and compare sustainability between different areas either statically or even dynamically, by analyzing the evolution of its values and its components for each of the communities. Such a function will make it possible in the future to track and monitor the results of institutional policies aimed at promoting sustainable development, which it would be desirable to start implementing at the

regional level, to serve at the same time as an element of convergence measurement beyond the traditionally used indicators based solely on quantitative economic growth.

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