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Modeling the Impact of Digitalization Factors on Territorial Development

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Abstract: Modern society is characterized by the expansion of the spectrum and the penetration of information technologies into all spheres of human activity. The widespread modernization of infrastructure and communications creates new opportunities for public administration, ensures an increase in the efficiency of the use of economic resources, and improves the quality of life. In this regard, the study of the regularity of the impact of digitalization on the balance of territorial development, smoothing socio-economic inequality of territories, stimulating economic growth is of particular importance. The object of the study is the processes of digitalization as a tool for spatial and economic development. The subject of the study is the assessment of the influence of digital transformation factors on the elimination of the imbalance of spatial and economic development of territories.

Keywords*: digitalization, mathematical model, balanced territorial development.*

1. Introduction

At the present stage of development, digital technologies are integrated not only into the branches of the national economy, but also into the management system at its various levels, modernize and optimize all spheres of human activity, form a new economic and territorial space. As a result, one of the fundamental tasks is to establish patterns of the impact of digital transformation on achieving sustainable and balanced territorial development, smoothing social and economic inequality of territories, stimulating economic growth, improving the well-being and quality of life of the population.

In the scientific literature, the issues of the strategy for the development of territorial space and the economy, including in the context of digital transformation, are widely represented in the works of both Russian and foreign scientists.

In particular, the issues of sustainability of economic development and the balance of its structure were considered by Bodenstein M. [1]., Wu J.[2], Pelli T.I.[3], Raskin P.D., Electris S., Rosen R.A. [4], Zubarevich N.V. [5] and others. According to the authors, it is the alignment of the economies of the territory that is necessary to ensure stability and growth.

Silvestrov S.N., Bauer V.P., Eremin V.V. emphasize the importance of investing in the manufacturing sector as a condition for the economic development of Russian regions. This, according to the authors, will increase the income level of the population, and therefore the income level of the regions themselves, which will guarantee the fulfillment of social obligations and contribute to an increase in the quality of life [6].

The problems of regional diversification were dealt with by Boschma R., Koenen L., Frenken K., Truffer B. K.[7], Kortinovis N., Jing Xiao, Van OortG. [8]. Considering the indicators of human well-being and the territory in which he lives, the authors show the main vulnerabilities: social problems, increasing inequality and income differentiation, concern about the employment prospects of the population, especially in connection with an increase in the retirement age. The problems of urbanization and poverty reduction were touched upon in the works of L. Christiansen, J. Werdt, and TodoY. [9]. Malkina M. Yu. assessed the impact of individual regions on the financial instability of the Russian economy [10,11].

In general, as most researchers note, the development of territories should be based on a competent scientifically developed policy [12,13]. At the same time, more and more authors note that one of the main factors in the development and improvement of the competitiveness of the national economy and individual territories is the introduction of digital technologies.

Kleiner G. B. analyzes the use of digitalization processes in making economic decisions and calls the "intellectual economy" the final stage in the development of digitalization [14].

Considering the problems of digitalization, the authors start from the interpretation of the concept of the digital economy and generalization of its essence. According to R. Bukht and R. Hicks, the digital economy is "... a part of the total volume of production, which is entirely or mainly produced on the basis of digital technologies by firms whose business model is based on digital products or services." [15]. At a time when there is a transition from the "primary" stage of digitalization – the creation of an Internet access infrastructure – to the "secondary" one, which represents the explosive growth of digital solutions, the stratification of regional digital potential and human capital of territories can be critical.

The exponential growth of technologies, which, becoming the engine of the development of new industries, make a significant contribution to solving global problems of mankind, changes the perception of the world, absolutely all spheres of society are being transformed: education and health systems, public administration, industrial production is changing, which manifests itself in the rapid transition from innovative projects to their implementation. In 2020, in the context of the pandemic, digitalization had a stimulating effect on overcoming the consequences of the socio-economic crisis, contributing to the creation and dissemination of new forms of business, the search for employees, partners, resources and sales markets. However, despite the scale of the impact of digital technologies on the transformation of socio-economic systems, many aspects remain insufficiently covered [16].

2. Objectives

The purpose of the study is to build a mathematical model that evaluates the relationship between the well-being of territories and the signs that determine the level of digitalization of regions, and an assessment of the degree of impact of each of them is given. It has been established that the main constraining factors of the transition to the digital economy are the low level of development of the necessary infrastructure, the implementation of internal costs for digitalization, and the innovative activity of organizations. It is proved that the activation of digital transformation processes is a strategic priority in the development of the territorial space and the economy.

3. Methods

The methodological basis of the study was the theoretical and methodological developments of domestic and foreign scientists and specialists, the systematization and development of which expands the understanding of the economic essence of the processes of digital transformation of economic systems and their impact on spatial development.

A stable, dynamic and balanced development of the region is facilitated by a legal environment that meets the requirements of the digital economy, which is both a goal-setting vector and a guarantor of protection from destabilizing factors. The systematization of existing development programs has made it possible to identify existing gaps, as well as possible directions for improving the system of legislation at various levels in order to accelerate the processes of digital transformation.

General scientific methods, such as abstract-logical, systematic approach, observation, analysis and synthesis, comparison, modeling, deduction, graphical method, etc., allowed us to reflect the main aspects of the research. The use of grouping methods, econometric calculations, graphical and tabular interpretation of data, and methods of decision theory made it possible to characterize the level and assess trends in digitalization. Software products MicrosoftExcel, StatsoftStatistica, PP INEK-Analyst 11.1 were used to process the initial information.

A regression analysis model of the dependence of the gross regional product by regions of the Russian Federation on a combination of factors determining the state of digitalization processes is constructed. Indicator Y is defined as an effective indicator: Gross regional product. The following explanatory features were selected:

X1: The proportion of organizations that used the Internet (as a percentage of the total number of surveyed organizations in the relevant subject of the Russian Federation);

X2: The share of high-tech and knowledge-intensive industries in the gross regional product;

X3: Number of personnel engaged in scientific research and development, per 1000 people;

X4: Internal research and development costs, million rubles per 1000 people;

X5: Advanced production technologies used, units per 1000 people;

X6: Patent applications for inventions filed units per 1000 people;

X7: Information about the use of intellectual property objects, units per 1000 people.

When constructing a multiple regression model, it is assumed that the dependence can be identified based on the Cobb-Douglas function:

$$\tilde{y}= \beta_0 \cdot (x_1)^{\beta_1} \cdot (x_2)^{\beta_2} \cdot (x_3)^{\beta_3} \cdot (x_4)^{\beta_4} \cdot (x_5)^{\beta_5} \cdot (x_6)^{\beta_6} \cdot (x_7)^{\beta_7} \quad (1)$$

The constructed model of nonlinear regression has the form:

$$y_i = \beta_0 \cdot x_{i1}^{\beta_1} \cdot x_{i2}^{\beta_2} \cdot x_{i3}^{\beta_3} \cdot x_{i4}^{\beta_4} \cdot x_{i5}^{\beta_5} \cdot x_{i6}^{\beta_6} \cdot x_{i7}^{\beta_7} \cdot \delta_i, \quad i = \overline{1,n} \quad (2),$$

where δ_i- are regression residuals.

Given that the relationship between the volume of GRP and the underlying factors is not direct or linear, logarithm is used to linearize the model:

$$ln\, y_i = ln\, \beta_0 + \beta_1 \cdot ln\, x_{i1} + \beta_2 \cdot ln\, x_{i2} + \beta_3 \cdot ln\, x_{i3} + \beta_4 \cdot ln\, x_{i4} + \beta_5 \cdot ln\, x_{i5} + \beta_6 \cdot ln\, x_{i6} + \beta_7 \cdot ln\, x_{i7} + ln\, \delta_i \quad (3)$$

or

$$y_i^* = \beta_0 + \beta_1 x_{i1}{}^* + \beta_2 x_{i2}{}^* + \beta_3 x_{i3}{}^* + \beta_4 x_{i4}{}^* + \beta_5 x_{i5}{}^* + \beta_6 x_{i6}{}^* + \beta_7 x_{i7}{}^* + \varepsilon_i,$$

где $y_i^* = ln\, y_i,\ \beta_0^* = ln\, \beta_0,\ x_{i1}{}^* = ln\, x_{i1},\ x_{i2}{}^* = ln\, x_{i2}, x_{i3}{}^* = ln\, x_{i3}, x_{i4}{}^* = ln\, x_{i4},\ x_{i5}{}^* = ln\, x_{i5}, x_{i6}{}^* = ln\, x_{i6}\ x_{i7}{}^* = ln\, x_{i7}, \varepsilon_i = ln\, \delta_i$ (4)

By converting the data in the formula bar, estimates of the coefficients of the regression equation are obtained, which confirm the validity of the proposed model.

4. Results

The problem of regional economic inequality is not unique to Russia. Thus, in the European Union, 43% of production volumes account for only 14% of the territory, in China, more than 60% of GDP is produced in only 4% of the territory. The level of per capita income in Luxembourg is 7 times higher than in Romania. Approximately the same ratio in terms of per capita GDP is observed in the most and least developed regions of China and India. Attention is drawn to the discrepancy between the domestic spatial development policy and the international experience of developed countries, where the direction of national regional policy is to stimulate the development of depressed territories and unload the largest centers or regions.

One of the factors leveling the possibilities of territories is the use of digital technologies. This allows you to simplify the promotion of goods, gives you the opportunity to declare yourself not only to an individual or a commodity producer, but also to entire municipalities. Thanks to digital technologies, not only procedures for obtaining public services or managing the region are accelerated, but also administrative barriers are reduced, lean technologies are introduced, interactive interaction services with potential buyers and business partners, financial and credit institutions. Digital technologies permeate all aspects of the living space and can become a driver of

growth in the quality of trade, tourism, medicine, education, finance, culture and others. It is both a development priority and a tool for smoothing territorial economic inequality, since residents throughout the territory receive equal access to digital opportunities.

The average number of people connected to the global network in Russia as of June 2019 was 80.9%. For comparison, the proportion of the population with Internet access in France is 92.3%, Great Britain – 94.9, Germany – 96.0, Sweden – 96.4, Norway – 98.4%.

As you can see, the problem of digital inequality is clearly manifested in the context of different territories. The level of digital skills of the population in Russia is noticeably lower compared to the indicators of most European countries. So, if the share of the population aged 16 to 74 years who did not use the Internet during the last three months in Russia in 2019 was 22%, then in Belgium and Spain – 10, Germany – 8, Finland and Great Britain – 5, the Netherlands – 4, Denmark and Sweden – 3%. The share of the population with a low level of proficiency in Russia was 39%, while in Belgium – 29, Germany – 22, Great Britain – 20, Finland – 19, the Netherlands – 16%. The share of the population with digital skills above the basic level in Russia was 12%, while in economically developed countries it is several times higher: in Belgium – 34, Germany – 39, Great Britain and Denmark – 49, the Netherlands and Finland - 50%.

According to the Global Innovation Index 2020 innovation systems assessment, Russia ranked 47th out of 131. Among the main elements of the Russian innovation index in 2020, only the level of business development, human capital and science, technology development and the knowledge economy had positive dynamics. The remaining indicators worsened their values compared to the previous year, with the most significant decrease in the infrastructure element.

In this regard, it is necessary to argue for the introduction of new digital technologies as a development tool. The impact of digital transformation on the economy can be proved mathematically, for example, using correlation and regression analysis, which allows to identify dependence. The application of the model proposed by the authors allowed us to establish the degree of relationship between GRP and the selected features (X1-X7).

The coefficient of the regression equation was estimated using the least squares method (OLS), which minimizes the deviation of the desired function from the actual observations.

Table 1.Estimation of coefficients of the regression equation

	Regression analysis results for the resultant variable: lnY Coefficient of determination = 0.38050613 Fisher Coefficient F(5.74)=2.5056 p<0.03758 Unbiased estimator of residual variance: 0.02088			
Number of observations (subjects of the Russian Federation)	OLS-estimation of the coefficient of the regression equation	Estimation of coefficient standard errors	Statistic value t(74)	p-value
Intercept	**4.221460**	**0.184543**	**22.87527**	**0.000000**
ln X7	*-0.005725*	*0.001824*	*-3.13940*	*0.002432*
ln X1	*0.080027*	*0.039761*	*2.01268*	*0.047787*
ln X3	0.004442	0.002704	1.64310	0.104604

ln X5	-0.005672	0.003123	-1.81612	0.073402
ln X2	0.008749	0.008096	1.08063	0.283369

The most significant influence is exerted by X7 "Information on the use of intellectual property objects". The second indicator in terms of the degree of influence is X1, "The proportion of organizations that used the Internet." The following shows signs of reducing the degree of influence on the performance indicator.

The Fisher coefficient allows us to conclude that factorial features do have a significant impact on the effective feature.

The p-value value confirms the validity of the model. The calculated value of p-value is <0.03758, which is less than 0.05, which means that factorial features have a significant impact on the effective feature.

The estimation of the equation has the form:

$$\underset{0}{Y^*} = \underset{(0,1845)}{4,2215} - \underset{(0,0018)}{0,0057} \cdot x_7^* - \underset{(0,0398)}{0,0800} \cdot x_1^* + \underset{(1,6431)}{0,0044} \cdot x_3^* - \underset{(0,0031)}{0,0057} \cdot x_5^* + \underset{(0,0081)}{0,0087} \cdot x_2^* \quad (5)$$

The analysis of regression residuals confirmed the hypothesis of a normal distribution, which suggests that the constructed model is adequate to the initial data.

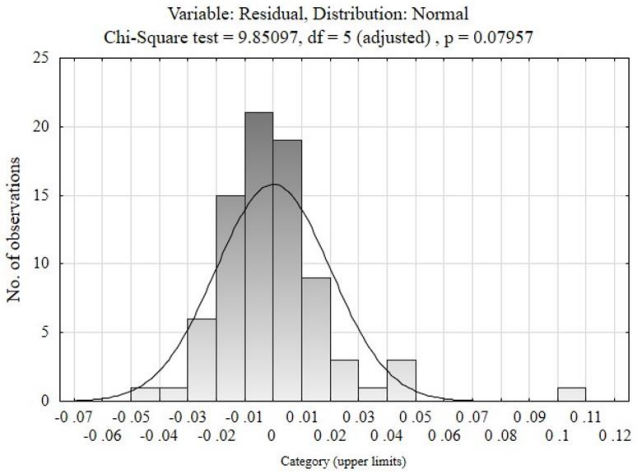

Figure 1: Histogram of the distribution of regression residuals

Checking for autocorrelation of regression residuals showed the following.

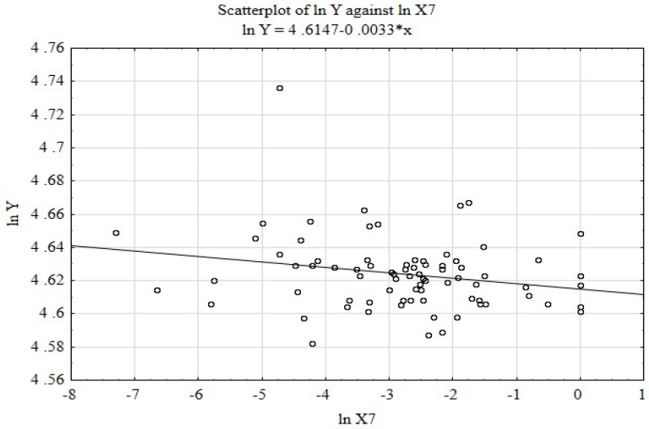

Figure 2: Graph of evaluation of the regression function and regression residuals of feature X7: Information on the use of intellectual property objects, units per 1000 people.

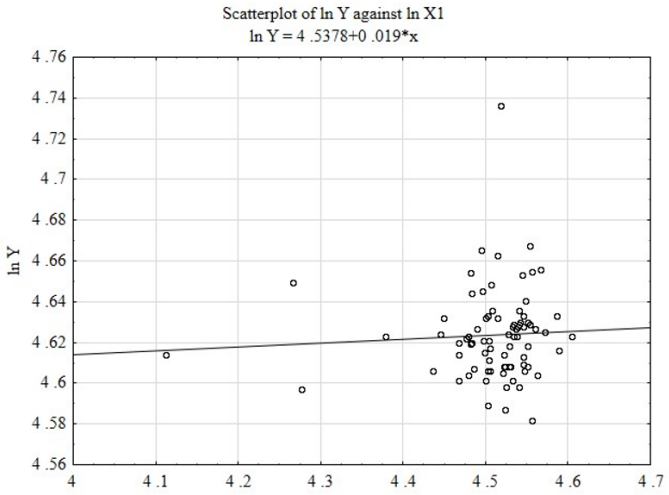

Figure 3: Graph of estimation of regression function and regression residuals of feature X1: The share of organizations using the Internet (as a percentage of the total number of surveyed organizations of the studied subject of the Russian Federation)

Graphical results confirm the absence of autocorrelation. This conclusion is confirmed by the Darbin-Watson statistical criterion.

Table 2.The value of the Darbin-Watson statistical criterion

	Durbin-Watson sequential correlation of residuals	
Evaluation	2.062350	-0.036088

To calculate the critical value of the criterion, this study uses the table of values of the Darbin-Watson statistics. In this case, for n= 85 (the number of studied subjects of the Russian Federation), k= 2 (signs X7 and X1), it is $d_h = 1.59$, $d_b = 1.69$. Since $d_{in}DW$, the conclusion is there is no autocorrelation.

Let's move on to the regression equation with the initial indicators:

$$Y = 68.1356 \cdot x_7^{0.9943} \cdot x_1^{0.9231} \cdot x_3^{1.0044} \cdot x_5^{0.9943} \cdot x_2^{1.0087} \quad (6)$$

The share of GRP variation due to changes in explanatory features is 38.05%, which confirms the importance of digitalization processes for the regional economy.

The calculations carried out showed that with an increase in the number of intellectual property objects used (feature X7) by 1 unit. (per 1000 people), GRP increases by 0.9943%.

An increase in the share of organizations using the Internet (as a percentage of the total number of surveyed organizations of the studied subject of the Russian Federation) (sign X1) by 1 unit will increase GRP by 0.9231%.

An increase in the number of personnel engaged in scientific research and development by 1000 people (sign X3) by 1 unit will contribute to an increase in GRP by 1.0044%.

The expansion of the advanced technologies used (by 1,000 people) (sign X5) by 1 unit will lead to an increase in GRP by 0.9943%.

An increase in the share of high-tech and knowledge-intensive industries in the gross regional product (sign X2) by 1 unit will increase GRP by 1.0087%.

5. Conclusion

The approach proposed by the authors made it possible to identify the factors characterizing the level of digitalization of territories. A mathematical model based on regression analysis made it possible to assess the degree of impact of each of them. Calculations confirm the reliability of the model and the existence of a connection between factorial features and effective. The use of this model is advisable when planning territorial development.

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