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Assessment of the Contribution of Inter-Territorial Interaction in the Development of the National Economy

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Abstract. Determination of the main indicators of economic growth is a key research question. In the course of solving this problem, many scientists agree that one of the drivers of economic development is interregional interaction. This article contains the results of a quantitative assessment of the role of interregional interaction for the Russian economy. The study is based on a modification of the Solow economic growth model which includes the level factor of interregional interaction. For a quantitative assessment of the effects of interregional interaction on economic development, a set of factors was determined that make it possible to assess the advantage that localization in a particular region can give to economic agents. The selected indicators have a direct impact on the potential and intensity of interregional interaction. The database for assessing the coefficients of the models and calculating the index of interregional interaction was formed on the basis of data from the website of the Federal State Statistics Service for the period from 2010 to 2018 for 83 regions of Russia. To select the best model of economic growth, considering interregional interaction, the authors evaluated different types of models: fixed effects model, time fixed effects model, random effects model, and time random effects model. The thesis about the importance of interregional interaction as one of the most important factors of production in modern Russia has found its empirical confirmation: the share of interregional interaction in ensuring the economic growth of Russian regions in the years 2015–2018 averaged 33%. The developed model of economic growth and the consideration of interregional interaction is universal and can be applied to various administrative-territorial units.

Keywords: Economic and mathematical modeling; Economic growth; Interregional interaction; Regional development; Solow model

1. Introduction

Sustainable development of the economy as a single integral system is impossible without the interaction of its constituent parts – regions. The interaction of territorial units realized through the cooperation of individual economic entities ensures the free movement of production, investment, and labor resources. Interregional communication has been proven to help strengthen cultural and business ties; optimize infrastructure placement based on regional cooperation; eliminate unnecessary financial costs associated with the creation of duplicate economic structures in the regions and unjustified

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interregional competition; combine resources and needs of territories to solve large-scale investment projects; and disseminate effective experience in the field of innovative development. All these processes are based on the principle of mutually beneficial cooperation that ensures the progressive development of the national economic system. Recognizing the practically axiomatic importance of interregional interaction for ensuring economic growth, it is important to note that scientists have not yet come to an agreement on a single generally accepted criterion reflecting the level of cooperation between territories. Indicators such as the dynamics of interregional trade or the ratio of Gross Regional Product (GRP) to the volume of wholesale trade reflect interregional ties, but represent only part of the overall picture of interregional interaction in terms of trade flows.

At the same time, while agreeing with Bakumenko (2017), we note that the method for assessing the dynamics of interregional resource flows to assess the intensity and, accordingly, forecasting the prospects of interaction is narrow: it covers only the economics of regional development and considers business as the only target group. Interaction cannot be complete if it does not cover such basic institutional structures as government, science, and business, cooperating with each other in order to achieve a high level of economic, social, and innovative development of the territory.

Based on the foregoing, as the goal of this work, a quantitative assessment of the role of interregional interaction in the economic development of the country is determined. The study was carried out by modifying the Solow economic growth model with the inclusion of the factor of the level of interregional interaction, which considers various aspects of interaction. Thus, the study examined the nature of the influence of interregional interaction on territorial economic growth.

2. Literature View

Establishing the main determinants of economic growth is one of the key research questions of interest to scientists since the time of Smith (2007). There are a large number of works that study the factors and causes of the development of economic systems, among which are basic indicators such as human capital (Mankiw et al., 1992; Basu and Bhattarai, 2012; Ahuru and James, 2015); scientific and technological progress (Goncharova and Bezdenezhnykh, 2018; Zhou and Luo, 2018), digitalization and innovation (Dvas and Dubolazova, 2018; Rudskaya and Rodionov, 2018; Akinwale et al., 2020), effective institutions and investments (Tebaldi and Mohan, 2008; Kapustina et al., 2016; Karpenko, 2019; Kudryavtseva et al., 2020), natural resources and favorable geographic location (Alkhathlan, 2013; Tukan et al., 2015; Bhattarai and Taloba, 2017; Ushakov et al., 2019); spatial effects (Bernat, 1996; Niebuhr, 2003).

At the same time, as a result of the modification of the Solow model in relation to the Russian regions, several interesting conclusions were drawn. For example, using data from 1998-2003, scientists confirmed the significant contribution of human capital to the economic growth of territories (Komarova and Pavshok, 2007). The model developed on the basis of the indicators of 1998–2014 (Zemtsov and Smelov, 2018) demonstrated the positive impact that a favorable investment climate and factors of technological innovation have on economic growth. The works of Popov (2001) and Libman (2010) show the importance of the quality of Russia's territorial institutions for economic growth. Kolomak (2010) proved the importance of spatial externalities for territorial economic growth in the analysis for 1996-2008. Cervantes and Dubrovskaya (2016) proved the key influence of natural resources on the economic growth of Russian regions.

Thus, the literature confirms the steady interest of scientists in the intensification of economic growth. However, we did not find quantitative estimates and empirical works

devoted to measuring the level of interregional interaction and determining its impact on economic growth. At the same time, for the Russian economy, which is characterized by high disproportions in inter-territorial development, the determinant of growth in the form of interregional interaction is perhaps one of the main factors. This is confirmed by the increased attention to the problem of territorial cooperation on the part of the country's highest authorities. The need to intensify interregional interaction is fixed and constantly updated in the regulatory documents and strategies for the development of the national economy. In this regard, the importance and timeliness of this study are evident.

3. Research Methods

The modeling of regional growth in this study was carried out on the basis of the Solow model by its decomposition considering the author's index of interregional interaction. The general view of the production function is the dependence of output on labor, capital, and interregional interaction in the current year (Equation 1):

$$Y(t) = K(t)^{\alpha} * I(t)^{\gamma} * [A(t) * L(t)]^{1-\alpha-\gamma} \quad (1)$$

where *Y(t)* is the aggregate output given by the performance-dependent production function; *L(t)* is the level of the labor indicator; *K(t)* is the level of physical capital; *I(t)* is the author's index of the assessment of interregional interaction; *A(t)* is neutral (according to Harrod (1973)) technical progress (such progress in which the labor factor grows faster than the increase in the number of workers); α is the contribution of the capital increase to the change in output; γ is the share of interregional interaction in the growth of output.

Fixed effects model (Equation 2):

$$ln(GRP_{it}) = \beta_i + \alpha * ln\, Sk_{it} + \delta * ln\, Sh_{it} + \gamma * ln\, I_{it} + u_{it} \quad (2)$$

where $i = \overline{1,83}$ is the region number; $t = \overline{2010,2018}$ is period of time; u_{it} is random error, all u_{it} are independent and equally distributed, $u_{it} \sim iid(0; \sigma_{\varepsilon}^2)$; α_i is the fixed effect of region i.

Random effects model (Equation 3):

$$\ln(\mathrm{GRP_{it}}) = \theta + \alpha * \ln Sk_{it} + \delta * \ln \mathrm{Sh_{it}} + \gamma * \ln \mathrm{I_{it}} + \varepsilon_{it} \quad (3)$$

where θ is a constant; $\varepsilon_{it} = \beta_i + u_{it}$, i.e. it is assumed that the individual effect of the region β_i is not a fixed value, but a random one, while $\beta_i \sim iid(0; \sigma_{\beta}^2)$, also a random individual effect, is part of the random error.

Based on the analysis of the works of Zemtsov and Smelov (2018) who assessed the coefficients of the model of economic growth, we determined the statistical indicators that best describe the factors of the model (Equation 1). Table 1 shows the selected model factors, their designations, and used indicators.

Table 1 Factors for assessing the model of economic development

Variable	Designation	Indicator
	Dependent variable	
Regional development	*GDPpc*	Ratio of the domestic regional product to the economically active population of the country / region, rubles / person
	The main factors	
The rate of saving of physical capital	*sk*	Ratio of investments of the last year to the GRP of the current one, %
Human capital savings rate	*sk*	Students per 10,000 people

Variable	Designation	Indicator
The index of the interregional interaction	*It*	The index reflects the level of interregional interaction of the region, how much the region is ready for interaction with other regions, %
Capital growth / decline	$n + g + \delta$	Growth rate of the economically active population +0.05

4. Statement and Description of the Research Problem

The database for estimating the coefficients of the models and calculating the index of interregional interaction (hereinafter referred to as index II) was formed on the basis of data from the website of the Federal State Statistics Service for the period from 2010 to 2018. For calculations, data were used for 83 regions of Russia, regions with incomplete information were not taken into account (Republic of Crimea and the city of Sevastopol).

First, it is necessary to clarify the choice of statistical indicators characterizing the factors of economic development. Note that in order to select the best indicators, various indicators of saving physical and human capital were tested for the factors *sk* and *sh*. Thus, the level of physical capital was considered as investment in fixed assets, the production index (which reflects the growth or decline of production and services in the region, excluding the construction sector), the cost of fixed assets, the ratio of last year's investments to the current GRP, and the ratio of the cost of fixed assets to GRP were considered.

To assess the norm of the labor indicator, we used indicators of the number of employed graduates (the share of employed urban dwellers with higher education in the population, which assesses the quality of human labor and the impact of agglomeration effects associated with the concentration and diversification of economic activity in cities). We considered the number of students per 10,000 people (the potentially highly skilled population of the region, which directly affects the level of human capital in the region).

The indicators that best describe economic growth were selected during 10 iterations. In each iteration 4 models were evaluated. On the basis of statistical tests, the best model was chosen, which included the indicator "the ratio of investments of the last year to the GRP of the current year" as an indicator of physical capital, and the indicator "number of students per 10,000 people" as an indicator of human capital.

To select the best model of economic growth, considering interregional interaction, the authors evaluated 4 models: fixed effects model, time fixed effects model, random effects model, and time random effects model. The choice of the best model of economic growth, considering interregional interaction was carried out on the basis of the information criteria of Akaike (1974) and Schwarz (1978), as well as on the basis of the results of statistical tests: F-test, Breusch-Pagan test and Hausman test. Based on the F-test results, a choice was made between Ordinary least squares (OLS) and fixed effects models. Using the Breusch-Pagan test, a choice was made between OLS and models with random effects. Hausman's test made it possible to make the correct choice between models with fixed and random effects.

Capital growth/decline rate ($n + g + \delta$) was calculated as sum the growth rate of the economically active population (where n is population growth rate) and 0.05 (amount rate of technological progress, g, and the depreciation rate of capital, δ).

We agree with the estimates of the study by Komarova and Pavshok (2007) that "the population growth rate n at the working age determines only to a small extent the differences in the regional growth rates of output". At the same time, Mankiw et al. (1992) used an approximate estimate of 0.05 for the sum of the constants $(g + \delta)$. As noted by Komarova and Pavshok (2007) "High depreciation of fixed assets of the Russian industry is

combined with a low rate of retirement", therefore we also adopted the indicator *(g + δ)* equal to 0.05.

The listed factors were used in the modified author's model, which also considered index II.

To quantify the effects of the interregional interaction on economic development, a set of factors was determined to assess the advantage that localization in a particular region can give to economic agents (firms, entrepreneurs, and individual specialists). The selected indicators have a direct impact on the potential and intensity of interregional interaction (Table 2).

Table 2 Factors for assessing the model of economic development

Designation	Statistical indicator, unit of measurement	Explanation
$x_{it}^{(1)}$	Share of the employed population with higher education, %	Share of employed with higher education in the *i*-th region in relation to the total number of employed population in the *i*-th region
$x_{it}^{(2)}$	Labor productivity index, %	The ratio of production results in the *i*-th region and labor costs for this production in the *i*-th region
$x_{it}^{(3)}$	Density of paved roads, km / km²	The ratio of the length of roads in the *i*-th region to the area of the *i*-th region
$x_{it}^{(3)}$	Average monthly accrued salary, rubles	Average salary in the *i*-th region
$x_{it}^{(5)}$	The number of people employed in the field of individual entrepreneurship, thousand people	The number of private entrepreneurs in the *i*-th region
$x_{it}^{(6)}$	Cost of living, rubles	The value of the subsistence minimum established by the Ministry of Labor of the Russian Federation for the *i*-th region
$x_{it}^{(7)}$	Trade balance, USD million	Difference between *i*-th region export and *i*-th region import

The calculation of the index of interregional interaction was carried out in several sequential steps:

1. Normalization of indicators.

To bring indicators to a single scale, a linear transformation was used

$$x_{it}^{j} = \frac{x_{it}^{j} - x_{min_t}}{x_{\max_t} - x_{min_t}} \quad (4)$$

where x_{it}^{j} -th is the indicator of the *i*-th region of the *t*-th year; x_{it} is a statistical indicator; x_{min_t} is the minimum value according to statistical indicators; $x_{\max_t}$ is the maximum value for statistical indicators; *j* is the number of the statistical indicator; *t* is the year for which the statistical indicator is taken; *i* is the region number.

2. Calculation of the index of interregional interaction.

The calculation of the index II of the *i*-th region includes the calculation of the induced potential indicator and the distance index for each region based on the selected statistical indicators according to the formula modified by the authors described by Zemtsov and Baburina (2016):

$$I_t = R * Z_t \quad (5)$$

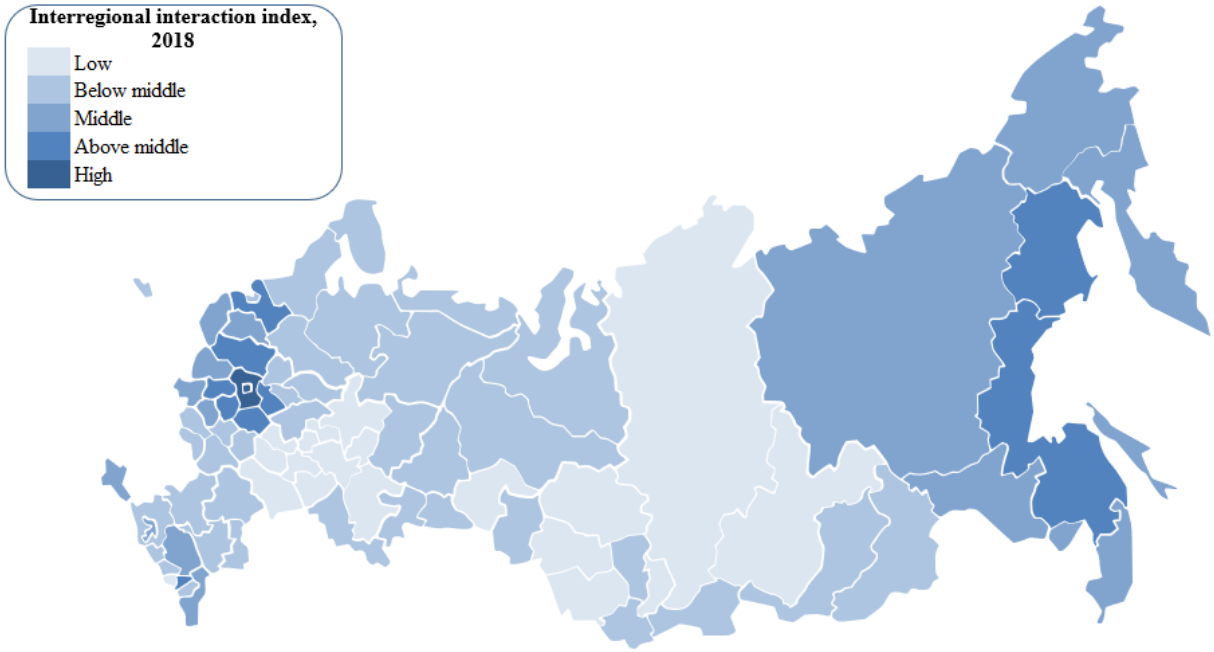
where I_t is a vector, the elements of which are I_{it} which is index II of the i-th region in the t-th year; R is a matrix of inverse distances, the elements of which are r_{kl}^2 which is the distance along the roads between the k-th and l-th regions; Z_t is a vector, the elements of which are z_{it} which is an indicator of the induced potential of interregional interaction in the i-th region for the t-th year.

In this case, the value of the indicator of the induced potential of the interregional interaction is found by the formula:

$$z_{it} = \frac{1}{m}\sum_{j=1}^{m} x_{it}^{(j)} \quad (6)$$

5. Results and Discussion

Based on statistical data (see Table 2), the authors calculated the index II values for the regions of Russia from 2010 to 2018. The values of the indices of interregional interaction range from 0.19 to 0.48. The national average is 0.213. The minimum value is in the Republic of Chuvashia, and the maximum is in the Moscow region and the city of Moscow (Figure 1). The simulation results are presented in Table 3.



Source: compiled by the authors

Figure 1 Distribution of the index II by constituent entities of the Russian Federation

Based on the results of statistical tests and information criteria, the fixed effects model was chosen as the best model to assess the impact of the level of interregional interaction on economic growth. According to the estimates obtained, all coefficients were statistically significant. With an increase in the number of students by 1%, the GRP level increased by 0.1%. An increase in the *Sk* indicator (the ratio of last year's investments to the current year's GRP) by 1% led to an increase in the GRP level by 1.06%. At the same time, it should be noted that an increase in the value of the interregional interaction index led to a decrease in GRP in the analyzed period. However, when time dummy variables were included in the fixed effects model, the coefficients for the variables *sh* and *It* became insignificant. In this regard, the period under consideration (2010-2018) should be divided into sub-periods.

Table 3 The results of evaluating economic growth models considering the index II

Variable		OLS model	Fixed effects model		Random effects model	
			-	Temporary effects	-	Temporary effects
Constant	const	5.88***	4.47***	6.17***	4.52***	6.22***
Physical capital savings rate	Ln(sk)	1.34***	1.06***	0.18***	1.07***	0.18***
Labor rate	Ln(sh)	-0.032	0.10**	-0.05	0.09**	-0.053
Index of the interregional interaction	Ln(It)	-0.55**	-1.12***	-0.004	-1.11***	0.043
Temporary effects	Dt	No	No	Yes***	No	Yes***
Model description						
Number of observations	N	747	747	747	747	747
Determination coefficient	R^2	0.06462	0.914242	0.978024		
Adjusted R^2	R^2adj	0.06084	0.6169	0.90184		
Model evaluation criteria						
F-тест		F(3,82)=13.56 Prob>F p-value =0	F(3,82)=364.3; Prob>F; p-value =0			
Breusch-Pagan test					chibar2=2218.77 prob>chibar2=0	chibar2=2738.43 prob>chibar2=0
Hausman test					χ^2=10.883; Prob> χ^2; p-value =0,12	χ^2=3.3087; Prob>χ^2; p-value =0,346
Schwarz criterion		1081.45	-160.92	-1125.102	1114.41	1012.36
Akaike criterion		1062.98	-557.90	-1559.012	1095.95	956.96

Note. *All variables are logarithmic (ln); robust standard errors; period 2010—2018; used observations 747; Dependent Variable: Ln (GDPpc); in the table, the symbols «*», «**», «***» mark the estimates that are significant at the level of 10, 5, and 1% respectively*

The authors chose 2 sub-periods: 2010-2014 and 2015-2018. The year 2014 was not chosen by chance – the economic sanctions introduced in this period had a rather strong impact on the development processes of Russia. Table 4 shows the results of evaluating fixed effects models in the context of two sub-periods.

Table 4 Results of evaluating economic growth models considering MRV in the context of sub-periods

Variable		Fixed effects model	
		2010-2014	2015-2018
Constant	const	6.49***	9.44***
Physical capital savings rate	Ln(sk_1)	1.28***	-0.005*
Labor rate	Ln(sh_2)	0.22***	-0.67***
Interregional Cooperation Index	Ln (I_t)	-0.59***	0.33***
Model description			
Number of observations	N	415	332
Determination coefficient	R^2	0.9466	0.9810
Adjusted coefficient of determination	R^2_a	0.5658	0.5598
Model evaluation criteria			
F test		F (3,82) =163.89 Prob>*F*=0	F (3,82) =4.77 Prob>*F*=0,004
Schwarz criterion		-150.35	-723.78
Akaike criterion		-496.78	-1086.32

Note. *All variables are logarithmic (ln). Dependent Variable: Ln (GDPpc); robust standard errors. In the table, the symbols «*», «**», «***» mark the assessments that are significant at the level of 10, 5, and 1%, respectively*

According to the results obtained, based on the Schwarz (1978) and Akaike (1974) information criteria, the best model was obtained for the period 2015-2018.

If we consider in more detail how the selected factors (*Sk1; Sh2; It*) influenced the average country level of GRP in the years from 2015 to 2018, it is evident that the variable *Sh2* was significant, but the number of students in the time interval between 2015 and 2018 negatively affected the average level of the country's GRP. Contrastingly, until 2014 this indicator had a positive effect on the GRP. This can be explained by the fact that before the global crisis, the country's economy was positively disposed towards investments in the education of citizens and there were no critically influencing negative external factors that required a large investment of resources. This is confirmed by the value of the coefficient of the *Sk1* indicator - the ratio of investments of the last year to the GRP of the current one, which also began to negatively affect the level of GRP, because all the country's savings, which were previously investments, were transferred to the restoring function of the country's economy.

One important change inherent in the model for 2015-2018 is a positive value of the coefficient at the variable of the index II, equal to 0.33 (with an increase in the index II by 1%, the GRP increases by 0.33%), i.e. the share of interregional interaction in ensuring the economic growth of Russian regions in 2015–2018, averaged 33%.

An objective explanation for the result obtained is the 2014 sanctions which led to the forced diversification of assets of national companies in terms of increasing investments in the domestic economy and an objective intensification of interregional relationships on this basis (Konnikov et al., 2018). These conclusions are consistent with the results of recent studies; they prove the reconstructive effect of sanctions on the country's economy in the post-crisis period. Thus, the simulation results show that interregional interaction is one of the important factors in the economic growth of regions.

6. Conclusions

We have found that the interaction of economic entities is an important condition for the effective functioning of the system of interregional relations, ensuring the even development of the country, which confirmed the hypothesis of the study. Thus, interregional cooperation plays a particularly important and significant role in the socio-economic development of both a separately selected region and the entire country. Therefore, when studying the development of interregional interaction, it is important to foresee the prospects and possibilities of its influence on economic growth.

In this work, a methodology for a quantitative assessment of interregional interaction was developed and its impact on the economic development of territories was estimated. The developed model of economic growth, taking into account interregional interaction, is universal and can be applied to various administrative-territorial units.

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