ANALYSIS OF THE IMPACT OF INFRUSTRUCTURE ON THE DEVELOPMENT LEVEL OF RUSSIAN REGIONS

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Abstract: Infrastructure is one of the main determinants of consistent and sustainable development in different countries and regions. Considering the Russian Federation, where there are 85 regions, not counting the federal cities, the problem of regional development and factors that can promote it, is currently of high importance. Different levels of regional development lead to higher economic differentiation between regions and cause serious damage to the Russian economy. Our main hypothesis suggests that a higher level of infrastructure development in a region positively affects economic development in the areas. Therefore, the main aim of our research is to estimate the impact of infrastructure on economic development in Russian regions using econometric analysis. In addition, cluster analysis was implemented to reveal the difference in infrastructural development levels in the regions. To provide a precise estimation, a database was constructed on Russian regions for the period of 2012 to 2016. The main method used in the research is econometric analysis and cluster analysis by using k-means method based on three main indicators: social, industrial and financial. The results of the analysis reveal 5 different clusters with highly differentiated levels of infrastructural development. Econometric analysis has shown that the most significant infrastructural factors are industrial factors and social factors. The results of the research could be taken into consideration as recommendations for development in order to improve government policy towards less developed Russian regions.

JEL Classification Numbers: O18, O47, **DOI**: 10.12955/cbup.v7.1347

Keywords: Infrastructure, infrastructure develoment of regions, static and dynamic indicators, real sector of economy, cluster analysis

Introduction

The definition of infrastructure has been considered by Donaubauer, Wang, Ayorinde, Gonzalez-Ruiz, Salim and others and correspond to the main functions of infrastructure, such as creating conditions for the development of the real sector of the economy and improving the quality of life of the population (Donaubauer et al., 2019; Wang et al., 2019; Ayorinde et al., 2019; Gonzalez-Ruiz et al., 2018; Salim et al., 2018). The main functions of infrastructure (economic, financial, demographic, social, and environmental) determine its functional content and structure. Inadequate infrastructure of the region, its inability to perform its inherent functions can be viewed as territorial infrastructure dysfunction, which cause problems related to manufacturing and social spheres. Realizing these functions, that infrastructure affects the economy and social sphere of the region by creating the most favorable conditions for their development.

In our research we determine three main types of infrastructure: industrial, financial and social. The industrial infrastructure is represented with transport, communications, electric power supply, and construction. Transport, being one of the largest sectors of economy and the most important component of the industrial infrastructure, provides necessary conditions for economic growth by increasing the competitiveness of the national economy and the quality of life of the population. Transport infrastructure improvement provides a region with a comparative advantage due to transaction costs reduction and accelerated communication between regions, which simplify resources usage and production delivery. The development of the fuel and energy complex addresses tasks such as providing enterprises and population with electricity, replenishing the state budget, ensuring energy and economic security of the country and regions. In addition, the positive impact of the power industry on regional growth is also achieved through spatial effects that go beyond the boundaries of individual constituent territories of the Russian Federation. The efficiency of a construction complex impacts on the formation of the material base for the development of the production complex and the non-productive sphere of the region. The construction complex contributes to the creation of capital

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funds and their extended reproduction, and the implementation of housing construction programs, thereby creating conditions for raising the living standards of the population.

Financial infrastructure creates conditions for ensuring the consolidation of financial resources, their rational distribution and use, and the creation of a favorable investment climate in a region. Banks, insurance and investment companies, stock exchanges, and non-budget state funds can be distinguished as the main financial institutions.

The social infrastructure of the region includes economic activities such as health, education and culture, public catering and consumer services, housing, etc. The main objective of social infrastructure is to support an adequate standard of living, to satisfy material and spiritual needs and to create conditions for the expanded labor reproduction and increased potential of a population in a region. Therefore, the social structure directly affects the improvement of quality of life, as well as the development of the regional economy, since it is a main factor in the formation of human capital that creates labor.

To justify optimal management decisions and prospective directions for a particular territory's development, it is necessary to estimate the actual state of the region's infrastructure and to compare it with other regions. In order to obtain comparative assessments of the state and endowment of regions with different types of infrastructure and to analyze its impact on regional development, it is important to select relevant indicators. Depending on the objective and the nature of the study, indicators can be absolute or relative, individual, grouped or general, static or dynamic.

Absolute measure reflects the level of infrastructure endowment in a region by its types or elements and is expressed in certain units, while relative indicators express the quantitative ratio of the two absolute values. Frequently, calculation of relative indices is based on the comparison of real state estimations with control values. For the purpose of this research, the highest values of infrastructure endowment can be applied as control ones. Partial indicators reflect the endowment of a region with certain infrastructural elements, whereas group (or consolidated) indicators represent its endowment with particular types and general (integral) –infrastructure as a whole. Estimation of consolidated and integral values is made based on partial indicators, which are preliminarily normalized with special algorithms. The list of partial and consolidated indicators of the infrastructure endowment of a region used in the research is presented in a Table 1.

Table 1: Groups of indicators by types and elements of infrastructure

No.	Types of infrastructure	Indicators
1	Industrial	i) Railway density of territory; ii) Density of highways with a hard surface; iii) Volume of innovative goods, works, services;
2	Financial	i) Deposits of legal entities and individuals in credit institutions per capita; ii) Investment per capita; iii) Direct foreign investment in US dollars per capita.
3	Social	i) Number of educational institutions of higher and secondary education per capita; ii) Turnover of public catering per capita; iii) The number of hospital beds per 10,000 people;

Source: Author

As Table 1 shows, the indicators are structured according to the types and elements of the infrastructure and are grouped into corresponding blocks.

It has to be mentioned that static indicators reflect the state of infrastructural endowment of regions in the current period. They can be partial, consolidated or integral. In order to calculate the indicators and to provide a comparative analysis, we have developed methodological recommendations that imply application of a number of specific procedures, which are described below.

Data and methodology

In order to calculate the indicators needed for analysis, a special information dataset based on the official site of the Federal State Statistics Service was constructed. The initial data for estimation of static and dynamic indicators covers all Russian regions for 5 years: from 2012 to 2016. From the dataset, static and dynamic indicators were estimated.

The algorithm of infrastructure assessment consists in a system of determining indicators and considering functions, which are fulfilled by each type of infrastructure. All the indicators were normalized by the max-min method (in order to trigger compatibility). The initial indicators and estimation equations are presented in the Table 2. Consolidated and integral indicators are used for a comparative assessment of infrastructure development by ranking and grouping constituent regions of the Russian Federation, determining the position of each territory within a particular macro-region or the country as a whole, depending on the level of infrastructure endowment in a given year.

Table 2: The consecutive order for indicators of infrastructure estimation

No.	Indicators	Calculation formulas	Notation
dynamic indicators			
1	Individual indicator ratio I ij	$I_{ij} = \frac{W_{ijt}}{W_{ij0}}$	W_{ijt}–the value of the i-th indicator for the j-th region in the current year t; W_{ijo}– the value of the i-th indicator for the j-th region in the base period; n – the number of individual indicators in the group (the elements of the infrastructure of this type); k – the number of groups of indicators (types of infrastructure).
2	A consolidated indicator of the dynamics of the region's security provided by the infrastructure of the type DSj	$D_{ij} = \sqrt[n]{I_1 * I_2 * ... I_n}$,	
3	Integral indicator of Dj	$D_j = \sqrt[k]{DS_{1_j} * DS_{2_j} * ... DS_{n_j}}$	
static indicators			
1	Normalized individual indicator: a) if the increase in the value of an individual indicator positively affects the integral estimate (increases its value); b) if the increase in the value of the individual indicator reduces the value of the integral estimate.	$W_{ij}^R = \frac{W_{ij} - W_i^{\min}}{W_i^{\max} - W_i^{\min}}$ $W_{ij}^R = \frac{W_i^{\max} - W_{ij}}{W_i^{\max} - W_i^{\min}}$	W_{ij}^R – the normalized estimate of the i-th index for the j-th region; W_{ij} – value of the i-th individual indicator for the j-th region; $W_i^{\min}$, $W_i^{\max}$ – the smallest and the largest values of the i-th index for all regions, respectively; i,j – indices of the indicator and region, respectively; λ_i – the weighing coefficient (relative contribution) of the i-th indicator; k – the number of groups of indicators (types of infrastructure) selected for assessing the infrastructure security of the region
2	Consolidated indicator of the region's security infrastructure of this type RSj	$RS_j = \frac{\sum_{i=1}^{n} \lambda_i \cdot W_{ij}^R}{\sum_{i=1}^{n} \lambda_i}$	
3	The integral indicator R	$R = \frac{\sum_{j=1}^{k} W_j}{k}$	

Source: Author

Classification by values of integral indicator for Russian regions was conducted through the k-means method. The k-means method is a type of cluster analysis, which is aimed at the division of observations on k clusters. In addition, each observation is related to a cluster, to the center of which the observation is closer. Cluster analysis is provided in order to compare the levels of infrastructure development in Russian regions.

For econometric analysis three methods for panel data estimation was used: ordinary least squares (OLS), random-effects (RE) and fixed-effects estimation (FE). For the variables we use the same indicators as for cluster analysis: GRP per capita and infrastructural indicators presented in Table 1. The initial equation for the econometric estimation is as follows:

$$GRP_{it} = \beta_0 + \beta_1 Railway + \beta_2 Highway + \beta_3 Goods + \beta_4 Deposits + \beta_5 Investment + \\ + \beta_6 FDI + \beta_7 Education + \beta_8 Catering + \beta_9 Hospital + \varepsilon_{it} \quad (1)$$

where the dependent variable is GRP_{it} – gross domestic product per capita as an indicator of economic development in a region i for the period t. Railway is railway density of territory (km per 10000 sq.m.

of territory), Highway - density of highways with a hard surface (km per 1000 sq.km of territory), Goods - volume of innovative goods, works, services, Deposits - deposits of legal entities and individuals in credit institutions per capita, Investment - investment per capita in rubles, FDI - Direct foreign investment in US dollars per capita, Education - number of educational institutions of higher and secondary education per capita, Catering - turnover of public catering per capita and Hospital - the number of hospital beds per 10,000 people.

Results and discussion

Based on the ranking and groupings of these indicators, a number of important analytical conclusions can be drawn. Thus, the consolidation of leading positions by certain regions over a number of years for selected indicators may indicate the positive stability of their socio-economic development, while the increase in the share of territories with small values of these indicators can be regarded as threats to the economic security of individual regions and the country as a whole, which must be taken into account when negotiating regional development strategies. The results of the provided cluster analysis, which is based on the estimated indicators, is presented in Table 3.

Table 3: Statistical characteristics of clusters of Russian regions

Value	Consolidated indicators by types of infrastructure			Integral indicator	GRPper capita, RUR
	Industrial	Financial	Social		
Group 1 (number of elements – 8): St. Petersburg, Moscow Region, Leningrad Region, Republic of Tatarstan, Kaliningrad Region, Rostov Region, Krasnodar Territory, Samara Region					
Maximum	0.599	0.221	0.498	0.420	712303.6
Minimum	0.303	0.059	0.279	0.231	300186.2
Mean	0.408	0.116	0.384	0.303	457467.0
Group 2 (number of elements – 1) – Moscow					
Maximum	0.664	0.686	0.436	0.595	1157373.0
Minimum	0.664	0.686	0.436	0.595	1157373.0
Mean	0.664	0.686	0.436	0.595	1157373.0
Group 3 (number of elements – 34): Belgorod Region, Lipetsk Region, Vologda Region, Murmansk Region, Novgorod Region, Perm Region, Nizhny Novgorod Region, Chelyabinsk Region, Republic of Bashkortostan, Udmurt Republic, Tula Region, Saratov Region, Ulyanovsk Region, Kursk Region, Tambov Region, Ryazan Region, Tver Region, Voronezh Region, Kaluga Region, Novosibirsk Region, Omsk Region, Primorsky Krai, Republic of Khakassia, Kemerovo Region, Oryol Region, Smolensk Region, Orenburg Region, Chuvash Republic, Vladimir Region, Bryansk Region, Kostroma Region, Pskov Region, Republic of Buryatia, Republic of North Ossetia					
Maximum	0.307	0.108	0.478	0.249	560380.2
Minimum	0.111	0.021	0.320	0.195	178390.3
Mean	0.216	0.056	0.400	0.224	327580.3
Group 4(number of elements – 23): Ivanovo Region, Republic of Karelia, Republic of Adygea, Republic of Kalmykia, Astrakhan Region, Republic of Dagestan, Republic of Ingushetia, Kabardino-Balkarian Republic, Karachaevo-Cherkess Republic, Chechen Republic, Stavropol Territory, Republic of Mari El, Republic of Mordovia, Kirov Region, Penzenskaya Region, the Kurgan region, the Republic of Altai, the Republic of Tyva, the Altai Territory, the Zabaikalsky Territory, the Jewish Autonomous Republic, the Republic of Crimea, the city of Sevastopol					
Maximum	0.210	0.053	0.466	0.201	371452.0
Minimum	0.027	0.003	0.128	0.088	106756.6
Mean	0.136	0.025	0.343	0.168	211402.8
Group 5(number of elements – 19): Yamalo-Nenets Autonomous District, Magadan Region, Chukotsky Autonomous District, Nenets Autonomous Okrug, Sakhalin Region, Khanty-Mansi Autonomous District, Khabarovsk region, Komi Republic, Sakha Republic (Yakutia), Kamchatka Territory, Sverdlovsk Region, Tyumen Region, Volgograd Region, Arkhangelsk Region, Krasnoyarsk Region, Irkutsk Region, Tomsk Region, Amur Region, Yaroslavl Region					
Maximum	0.431	0.429	0.610	0.411	5821559.8
Minimum	0.169	0.063	0.374	0.238	292567.7
Mean	0.258	0.143	0.488	0.296	1152625.7

Source: Author

The results of the cluster analysis have confirmed that Russian regions are highly differentiated. The leader in infrastructural development is Moscow, which comprises cluster 2. The integral indicator is the highest - 0.595. At the same time, Moscow shows the highest volume of GRP per capita, which adds evidence that regions with more developed infrastructure are more economically advanced. Cluster 1 shows also quite high indicators, which comprises regions, located closer to Moscow. Other clusters show quite low values of indicators. The main problem that can be derived is that the majority of Russian regions has very low levels of infrastructural development and lower values of GRP. Considering the result, the government should provide more aid to regions from cluster 3, 4 and 5.

The results of the econometric analysis give a possibility to reveal the most significant infrastructural factors that should be improved in order to achieve a higher level of economic development. The results are presented in Table 4.

Table 4: The results of econometric estimation

Dependent variable: GRP per capita (in RUR)	OLS	FE	RE
Railway density of territory (km per 10000 sq.m. of territory)	0.0241***	0.327**	0.0154***
Density of highways with a hard surface (km per 1000 sq.km of territory)	0.01057	0.0952***	0.0489***
Volume of innovative goods, works, services (share of GRP)	0.723***	0.759***	0.801***
Deposits of legal entities and individuals in credit institutions per capita (share of GRP)	0.567***	-0.136	0.0621
Investment per capita (RUR)	0.835***	0.713***	0.746***
Direct foreign investment in US dollars per capita	55.198***	49.93***	46.512***
Number of educational institutions of higher and secondary education per capita	24.65***	45.223***	30.56***
Turnover of public catering per capita	0.0813*	-0.264***	-0.147
The number of hospital beds per 10,000 people	0.035	0.041	0.0072
Wald Test/F-test	2489.392***	3742.12***	24397.52***
Breush-Pagan test	1479.24***		
Hausman test	187.59***		
Levels of significance: *** p < 0,01, ** p < 0,05, * p < 0,10			

Source: Author

According to results of the econometric analysis, the regression is significant as a whole, which the Wald Test confirms. There were also two additional tests provided: the Breush-Pagan test and the Hausman test, that show which estimation method best fits the model. The Breush-Pagan test compares an ordinary least squares method with a random-effects one. As the result shows, the RE-method fits better for the model, then OLS. The Hausman test compares the FE-method with the RE-method. According to the result of the Hausman test, the random-effects method is more preferable. The most significant factors that affect GRP per capita are industrial factors (all of them are significant at 1% significance level), especially volumes of innovative goods, works and services. The improvement of the factor by 1 unit would lead to an increase of GRP per capita by 0.801 units. From financial factors the most significant one is foreign direct investment. An increase of FDI by 1 unit will increase the GRP per capita by 46.512 units on average. Deposits of legal entities and individuals into credit institutions per capita appeared to be insignificant.

Social factors show less significance except the number of educational institutions of higher and secondary education per capita. This factor is significant at the 1% level and increase of educational institutions by 1 unit will lead to an increase of GRP per capita by 30.56 units.

Conclusion

The research provides two types of analysis: cluster analysis and econometric estimation. The result of the cluster analysis revealed 5 groups of Russian regions which are highly differentiated by all indicators. The leaders among the regions in infrastructure development are cluster 1 (Moscow) and cluster 2 (St. Petersburg, Moscow Region, Leningrad Region, Republic of Tatarstan, Kaliningrad Region, Rostov Region, Krasnodar Territory, Samara Region). The result show that the largest cities (federal ones) and areas located close to them have better infrastructure development and higher volumes of GRP per capita. In order to provide sustainable economic development of Russian regions,

more attention and government aid has to be paid to regions with less developed infrastructure (more than 50% of all Russian regions).

The results of the econometric estimation derived the specific factors that can be more significant to increase economic development of regions. Therefore, the provision of innovative goods, works and services will lead to economic improvement faster, as well as foreign direct investment and number of educational institutions. These are the main infrastructural determinants that are recommended to be improved in the regions from cluster 3, 4 and 5. Construction of railways and highways will also provide a rapid improvement of economic development in regions due to decreases in transaction costs and enhancement of interregional communication. The results of the tests have shown that the model is relevant, and estimation is robust. Therefore, the results of the research can be implemented by state and regional government to provide sustainable economic development in Russia.

Acknowledgements

This research is supported by Institute of economics of the Ural Branch of the Russian Academy of Sciences (the state order of the Federal Agency of Sciences and Education of Russia of the Federal State Budgetary Establishment of Sciences, Program No. AAAA-A16-116031410059-5, 2018).

References

Ayorinde E., Aigbavboa C., Ntebo N. (2018) A Theoretical Assessment of the Challenges Facing Power Infrastructure Development in Low-Income Countries in Sub-Sahara Africa. In: Ahram T. (eds) Advances in Artificial Intelligence, Software and Systems Engineering. AHFE 2018. Advances in Intelligent Systems and Computing, vol 787. https://doi.org/ 10.1007/978-3-319-94229-2_53

Cerra V., Cuevas A., Goes C., Karpowicz I., Matheson T., Samake I., Vtyurina S. (2017) Determinants of Infrastructure and Its Financing. *Emerging Economy Studies*, vol. 3, pp. 113-126.

Donaubauer J ., Herzer D., Nunnenkamp P., (2018) The effectiveness of aid under post-conflict conditions: a sector-specific analysis *Journal of development studies* Volume 55 Series 4: 720-736, https://doi.org/10.1080/00220388.2017.1400013

González-Ruiz J., Botero-Botero S., Duque-Grisales E. (2018) Financial Eco-Innovation as a Mechanism for Fostering the Development of Sustainable Infrastructure Systems *Sustainability*, 2018, https://doi.org/10.3390/su10124463

Munyasya B.M., Chileshe N. (2018) Towards Sustainable Infrastructure Development: Drivers, Barriers, Strategies, and Coping Mechanisms. *Sustainability* Volume 10 Series 12, https://doi.org/10.3390/su10124341

Pagano M. A., Perry D. (2008) Financing Infrastructure in the 21st Century City. *Public Works Management & Policy*, vol. 13, pp. 22-38, doi/10.1177/1087724X08321015

Rybeck R. (2004) Using Value Capture to Finance Infrastructure and Encourage Compact Development. *Public Works Management & Policy*, vol. 8, pp. 249-260.

Salim, W. & Negara, S. D. (2018). Infrastructure Development under the Jokowi Administration: Progress, Challenges and Policies. *Journal of Southeast Asian Economies* (JSEAE) 35(3), 386-401. https://doi.org/10.1355/ae35-3e

Wanga J., Zuoa W., Rhode-Barbarigosb L., Lua X., Wangc J., Lind Y. (2018) Literature review on modeling and simulation of energy infrastructures from a resilience perspective, *Reliability Engineering & System Safety* ,Volume 183: 360-373 https://doi.org/ 10.1016/j.ress.2018.11.029