ANALYSIS OF URBAN CONNECTIVITY EFFECTS OF THE SOUTHERN FEDERAL DISTRICT[1]

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Abstract

Today, existing urban imbalances in Russia distort the territorial space, demonstrate its insufficient integrity, which leads to high differences in the quality of life of citizens and social instability. In order to make effective and scientifically sound management decisions, it is necessary to understand the mechanisms underlying the functioning of cities, which actualizes the study of the effects of their connectivity in territorial space.

The aim of the study is to develop an approach that allows us to determine the effects of urban connectivity in territorial space. The estimation method is based on the calculation of global and local Moran indices to determine the effects of the connectivity of territories by indicators: "population size", "migration growth", "volume of shipped products per capita". The information base was the data of the Federal State Statistics Service, the calculation of distances was carried out according to the data of the automobile portal. The object of the study is the cities of the Southern Federal District, with a population of more than 100 thousand people in 2017. The calculations made it possible to determine the type (direct and reverse) and the strength of inter-territorial relations according to the parameters under consideration: according to the indicator "population size" there is a negative autocorrelation, according to the indicator "migration growth" and "volume of shipped products per capita" - positive autocorrelation. According to the indicator of the volume of shipped products per capita, polarization was revealed: Volgograd and Volzhsky are disconnected from the rest of the group of cities, while they do not have a significant impact on nearby territories. The strongest direct inter-territorial links are identified in the group of leading cities relative to each other. The indicator of «migration growth» observes significant inverse effects, largely Maykop falls into the zone of influence of leading cities.

The practical importance lies in the possibility of using the results obtained by regional authorities in developing a strategy for the development of cities and regions in terms of identifying the production clusters of the region.

Keywords: Moran index, spatial autocorrelation, inter-territorial connection, city
JEL classification: R12

1. Introduction

The current differences in the socio-economic development of the cities and regions of the Russian Federation have a significant impact on the state structure, the structure and efficiency of the economy, and the strategy and tactics of institutional changes. The management of the spatial development of cities is becoming more important in the Russian Federation, which is determined primarily by the high inter-territorial differentiation according to a number of key indicators. Population, investment, services are unevenly distributed in the territory of the Russian Federation: there is a significant concentration in the central part of the country (Moscow, Moscow region, Saint Petersburg) and the effect of dispersal from the center to the East.

Existing urban disparities distort spatial space and demonstrate its lack of integrity, which leads to high disparities in the quality of life of urban dwellers and social instability. Effective and scientifically based management decisions require an understanding of the mechanisms,

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conditions and factors underlying the functioning of cities, which updates the study of their connectivity effects in the territorial area of regions and in the country as a whole.

The aim of the study is to develop an approach for determining the effects of urban connectivity in the territorial area.

2. Literature review of the study

To conduct this study, a detailed analysis of the literature was carried out in two directions: the spatial development of cities and the theory of spatial autocorrelation.

In foreign scientific literature at the end of the 20th century, the urban agglomeration economy, singled out, as a field of knowledge from the new economic geography, became a popular direction. Economists try to explain the role of city size (population) in economic efficiency and to assess the interaction of cities. The underlying principle of the theoretical models is that, in industrialized countries, not only a large part of the population but also economic activity is concentrated in cities, and urban structure is the result of the dynamic interaction of economic activity and urban growth [Gabaix, 1999; Duranton, 2007; Corboda, 2008].

Particularly popular is the urban growth theory presented in the works of K. Gabaix [Gabaix, 1999], J. Eeckhout (2004) [Eeckhout. 2004], M. Partridge, D. Rickman, C. Ali, M. Olfert [Partridge et al, 2008], K. Schlüter, A. Lalanne, M. Zumpe [Schlüter et al, 2015]. Urban growth models are based on a balance of advantages, the costs of agglomeration, economic forces such as employment, transport costs, market potentials and technological innovation. A number of models offer similar deterministic factors that are fundamental to explaining the complex dynamics of urban hierarchies.

The problem of the location and development of cities in the spatial economy is gaining in importance in the work of Russian scientists at the beginning of the 21st century. A.I. Trejvish assessed the dynamics of the rank of Russian cities from 1967 to 2002 and concluded that in a significant part they (ranks) remain. This conclusion confirms the stability of the urban system of the Russian Federation [Trejvish, 2009]. A. M. Arhipov developed a functional typology of cities with the allocation of features: the degree of development of the functional structure, territorial content of functions, economic and geographical location [Arhipov, 2010]. Andreev evaluates the location of cities in the Volga Federal district using the Zipf law [Andreev, 2017]. E. A. Kolomak presented empirical patterns of development of the Russian urban system, analyzed the level of urbanization, and offered econometric estimates of factors of development of the urban system [Kolomak, 2018].

Spatial autocorrelation theory has been a key element of geographical analysis for more than twenty years. The availability of large data sets with spatial reference and complex visualization capabilities have created a need for new methods of spatial data analysis, both research and confirmatory [Anselin, 1992; Openshaw, 1993]. Spatial structural instability or spatial drift has been included in a number of modeling approaches. Discrete spatial modes are taken into account in the analysis of variance [Griffith, 1978; Griffith, 1992; Sokal et. al., 1993] and in regression models with spatial structural changes [Anselin, 1988; Anselin, 1990]. A number of spatial correlation measurements are proposed to study the spatial process of geographical evolution from different points of view [Bivand, 2009; Haining, 2009; Li et. al., 2007; Tiefelsdorf, 2002; Weeks et. al., 2004]. The most popular tool for measuring correlation is the Moran index [Moran, 1948], which is a generalization of the Pearson correlation coefficient. Concepts and methods of spatial autocorrelation have been applied to many areas, resulting in a number of interesting results. Chen reconstructed the matrix of spatial weights and the Moran index and, improving the scattering graph, presented four approaches to calculating the Moran index, which contributed to the development of the analytical process of spatial autocorrelation [Chen, 2005]. Yu. V. Pavlov and E. N. Koroleva apply the local and global Moran index to identify clusters and subclusters. Scientists have identified four territorial clusters and six subclusters in the Samara region [Pavlov, Koroleva, 2014]. V. A. Rusanovskij and V. A. Markov use the Moran index to measure the spatial localization of unemployment. This index gives correct results for complex systems when relations between neighboring territories are linear [Rusanovskij, Markov, 2016] A.V. Suvorova using the Moran index developed an approach for identifying direct and inverse effects of the development of growth poles, and measured the scale of their influence on the territories centered around [Suvorova, 2019].

3. Research methodology

When analysing the spatial characteristics of cities, priority is given to the characteristics of their population, the proximity of the objects, the scale of the systems and their concentration within the territory. Spatial econometric techniques - the calculation of global and local Moran indices - are useful for determining the effects of urban connectivity, which will make it possible to determine the degree of coherence of the parameters characterizing the development of neighboring cities.

The methodology for assessing urban connectivity using the Moran index consists of the following steps:

1) Collection of statistical data, construction of a matrix containing information on the distances between all territorial units studied (in this study - cities within the boundaries of the Southern Federal District). The distance matrix will be based on information on the length of roads between cities of the Federal District.

2) Calculation of the global Moran index by the formula:

$$I_G = \frac{N}{\sum_i \sum_j w_{ij}} * \frac{\sum_i \sum_j wij(x_i - \mu)\ (x_j - \mu)}{\sum_i (x_i - \mu)^2} \quad (1)$$

Where I_G is the Moran Global Index,

N is the number of cities;

w_{ij} is an element of the spatial balance matrix for the names of the hyons i and j;

μ - the average value of the indicator;

x is the analyzed measure.

3) Calculation of the mathematical expectation of the index:

$$E(\mathrm{I}) = \frac{-1}{\mathrm{n}-1} \quad (2)$$

where $E(I)$ is the mathematical expectation of the index,

n is the number of territories analysed.

4) Determination of the existence and nature of spatial autocorrelation.

$I_G \geq E(I)$ is a positive spatial autocorrelation (the values of the indicator in question are close to each other for neighbouring cities);

$I_G \leq E(I)$ is a negative spatial autocorrelation (the values of the indicator of neighboring cities differ).

$I_G = E(I)$ - no spatial autocorrelation [Rusanovskij, Markov, 2016].

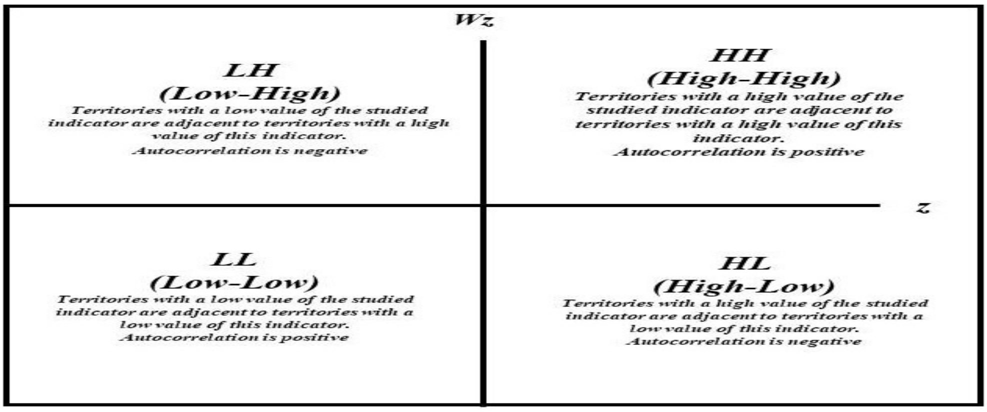
5) Verification of the significance of the obtained results by the method of statistical hypothesis testing (z-test), by determining the value of Z-statistics:

$$z - stats = \frac{I - E(I)}{\sqrt{E(I)^2} - E(I)^2} \quad (3)$$

The value obtained is the number of standard deviations by which the actual value of the Moran index is removed from the expected value.

6) Construction of the spatial Moran scatter diagram. The abscissa axis is the standardized z -values of the studied indicator, and the ordinate axis is the values of the spatial factor Wz. The diagram reproduces the regression line Wz by z, the slope of which is equal to the coefficient of total spatial autocorrelation I for a standardized weight matrix. The spatial autocorrelation coefficient demonstrates the degree of linear relationship between the z vector of centered values of the studied indicator and the Wz vector of spatially weighted centered values of the studied indicator in neighboring cities (regions) [29] (Fig.1).

Figure 1. Spatial dispersion diagram of the Moran index



7) Calculate the values of the local Moran index *(LISA* - Local Index Spatial Autocorrelation), determine the tightness of a particular city's connection to all others.

$$I_{L_i} = z_i \sum w_{ij} z_j \tag{4}$$

where

I_{Li} is the local Moran index for the *i*-city;

w_{ij} is the standardized distance between *i* -th and *j* -th city;

zi and *zj* are the standardised values for the *i*-th and *j*-th city.

The values obtained may range from -1 to 1.

For I_{Li} < 0, the negative autocorrelation for the city *i*. i.e. the given city by this value differs significantly from the neighbouring city (outlier).

For I_{Li} > 0, the autocorrelation is positive, i.e. the given city is similar to neighboring cities (cluster).

For | I_{Li} | > | I_{Lj} |- similarity/difference of cities *i* with surrounding neighboring cities is greater than for city j and its neighbors.

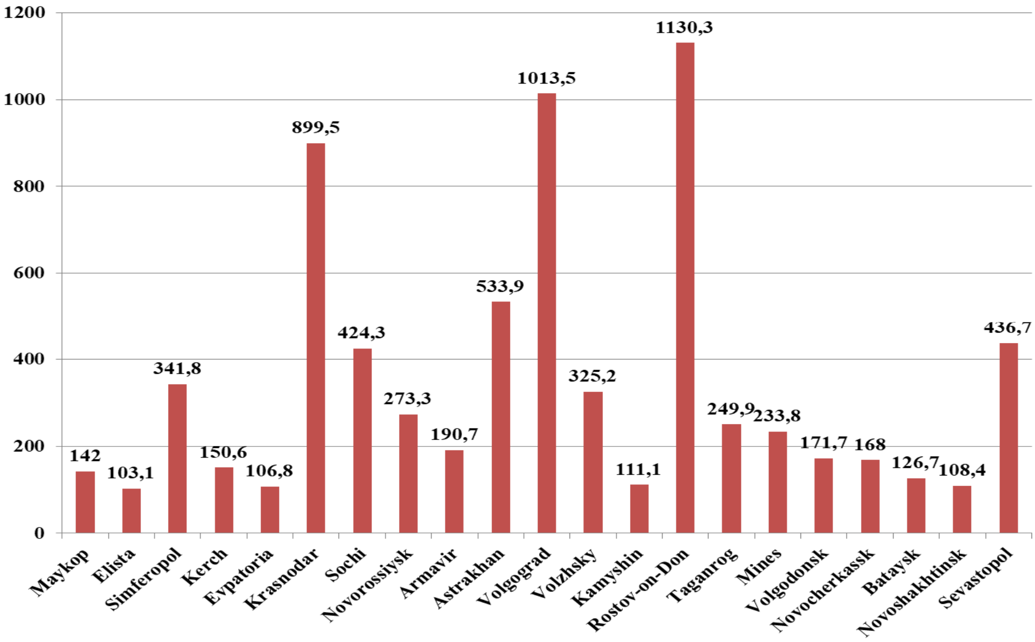
A sample of cities in the Southern Federal District with a population of more than 100,000 people was selected for the study. Poor municipal statistics and the lack of some indicators make it impossible to include the remaining group of cities in the analysis.

Analyzed indicators: population size, migration growth, volume of goods shipped per capita. Period of study - 2017. The source of the information was data from the Federal State Statistics Service; the distances were calculated from the data from the car portal.

4. Results of the author's study and discussion

The indicators analyzed in the study are the resulting parameters for the socio-economic development of the city (fig. 2-4). Population size and migration growth are indicators of the success of urban development. Volume of goods shipped per capita - scale and success of economic activity of the city.

Fig. 2 Population of the cities of the Southern Federal District in 2017, thousands of people.



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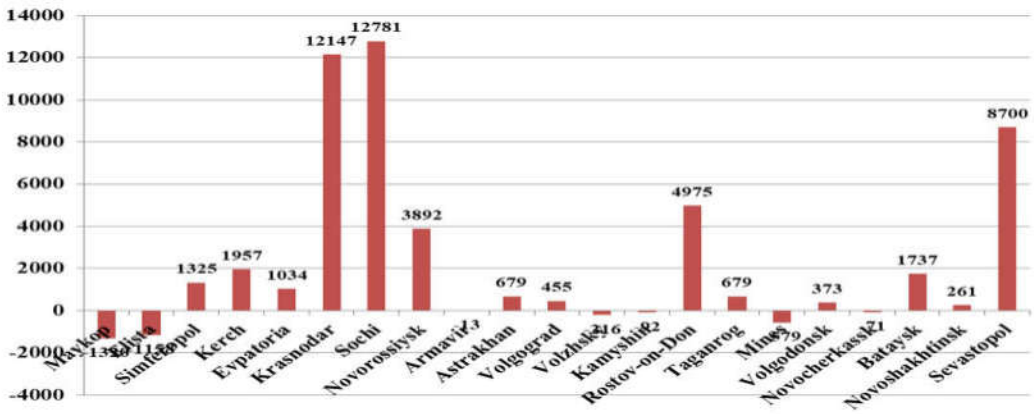
In the territory of the Southern Federal District in 2017, there are two millionaire towns. Rostov-on-Don and Volgograd. The largest share of the sample is in cities with less than 400,000 inhabitants. (15 cities). In general, data in figure 2 show a wide differentiation of the surveyed cities according to the index «population of the city»

Figure 3. Migration growth in the cities of the Southern Federal District in 2017, people



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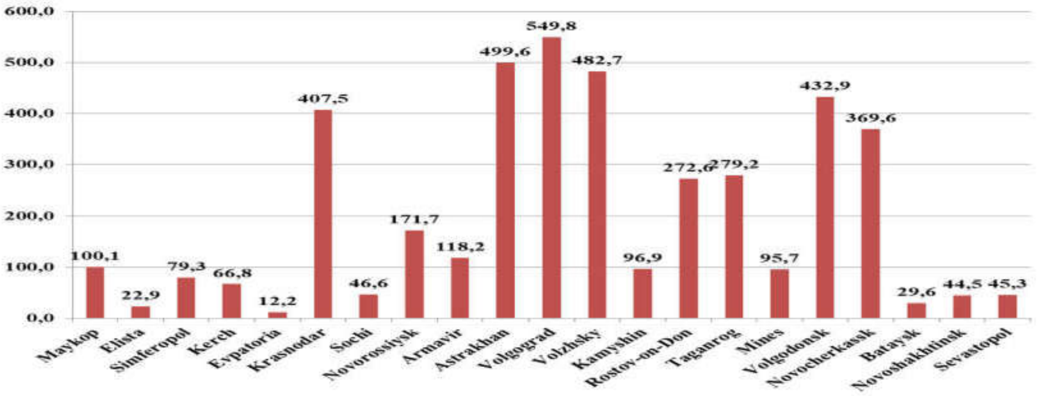
The figures in figure 3 show a mixed picture of migration growth in the cities of the Southern Federal District: some cities are experiencing a significant influx (Krasnodar, Sochi, Sevastopol), some are experiencing a significant decline (Maikop, Elista, Shakhty), which generally shows a wide differentiation of socio-economic development in the cities of the federal district surveyed.

Figure 4. Volume of goods shipped per capita in cities of the Southern Federal District in 2017, thousands of rubles.



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Maximum values of the index «volume of goods shipped per capita» are observed in Volgograd and exceed minimum values (Evpatoria) 45 times. In general, the cities leading on this indicator are Krasnodar, Astrakhan, Volgograd, Volga, Volgodonsk and Novocherkassk.

Figures 5, 7, 9 show the spatial scatter diagrams of the global Moran Index for the analyzed indicators in 2017 in the Cities of the Southern Federal District. Tabular representations of the local Moran index are given in tables 1-3. Graphical representations of the local Moran index of cities located in squares *HH* and *HL* are presented in figures 6, 8, 10.

Fig. 5 The spatial distribution of Moran (population) for the cities of the Southern Federal District in 2017.

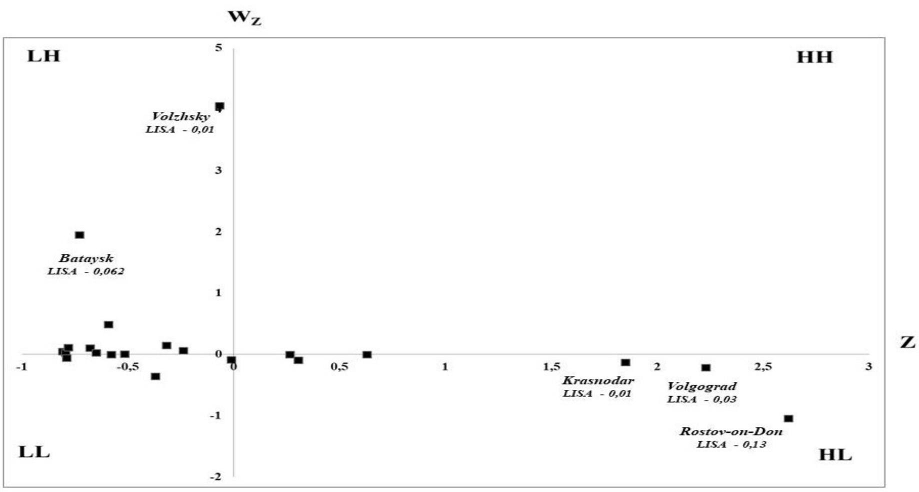

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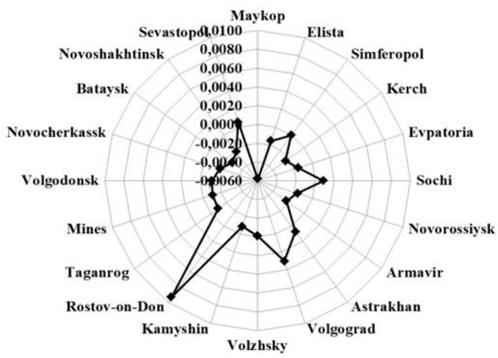
Table 1 Tabular representation of the spatial distribution of Moran for the cities of the Southern Federal District (population) in 2017.

LH				HH			
City	Z	Wz	LISA	City	Z	Wz	LISA
Maykop	-0,67677	0,1038	-0,00335				
Elista	-0,80657	0,0463	-0,00178				
Kerch	-0,64807	0,0222	-0,00069				
Evpatoria	-0,79422	0,0275	-0,00104				
Novorossiysk	-0,23866	0,0576	-0,00066				
Armavir	-0,51427	0,0055	-0,00014				
Volzhsky	-0,06548	4,0635	-0,01267				
Kamyshin	-0,77987	0,1084	-0,00403				
Taganrog	-0,31673	0,1443	-0,00218				
Novocherkassk	-0,59001	0,4880	-0,01371				
Bataysk	-0,72782	1,9510	-0,06762				

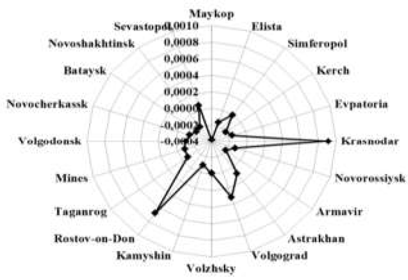
LL				HL			
City	Z	Wz	LISA	City	Z	Wz	LISA
Simferopol	-0,01009	-0,09318	0,00004	Krasnodar	1,8508	-0,1307	-0,01
Mines	-0,37046	-0,3564	0,006	Sochi	0,2651	-0,0049	-0,001
Volgodonsk	-0,57767	-0,00115	0,0001	Astrakhan	0,63089	-0,0066	-0,002
Novoshakhtinsk	-0,78888	-0,05839	0,002	Volgograd	2,23118	-0,2145	-0,02
				Rostov-on-Don	2,62091	-1,0523	-0,13
				Sevastopol	0,3065	-0,0946	-0,01

Compiled from: Regions of Russia. Main socio-economic indicators of cities 2018: Stat. Sat. / Rosstat. - M., 2018.S., 172-208.

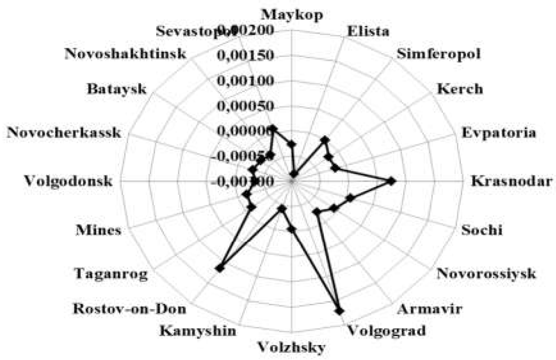
Figure 6 Local Index (*LISA*) Moran in a sample of cities of the Southern Federal District (population) in 2017.



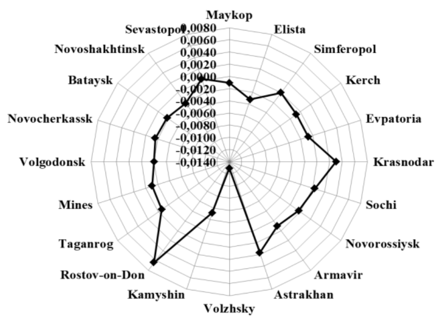
A) Krasnodar



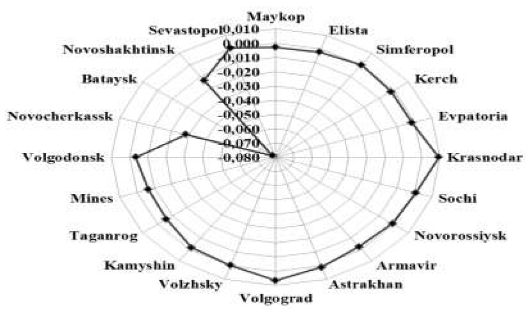
B) Sochi



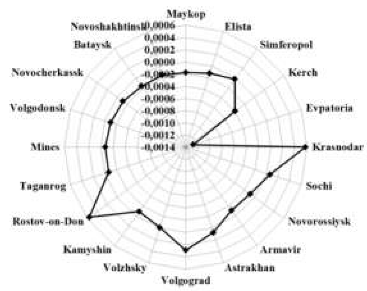
C) Astrakhan



D) Volgograd



E) Rostov-on-Don



D) Sevastopol

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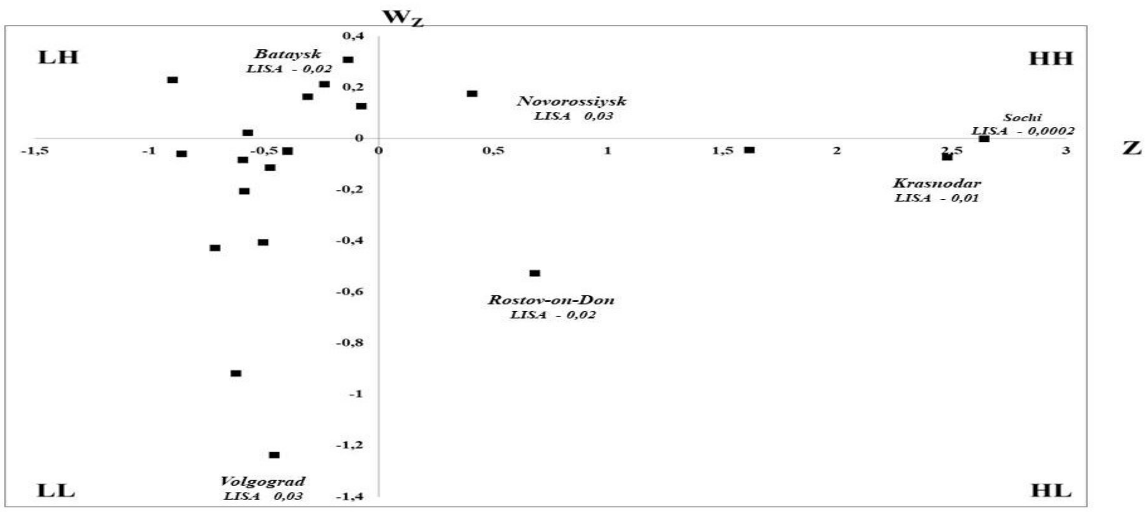
The population of the Southern Federal District obtained a global Moran index of -0.3 with a mathematical expectation of -0.05. Thus, we can conclude that there is a negative autocorrelation, i.e. neighboring cities are more likely to have different values for the analyzed indicator. There are no cities in the Federal District with a relatively large population and no neighbors with a relatively high ratio. Five cities are located in the *HL* square, with the greatest interaction demonstrated by Krasnodar (*LISA* - 0.01146). The maximum number of cities in the different regions of the Federal District surveyed fell into the *LH* square. Three cities of Rostov Oblast and one republic of Crimea are located in the square *LL*.

Looking at the nature of the connections of cities with relatively high values of the measure (*HH* squared and *HL*), it was concluded that the strongest direct links between these cities were observed relative to each other (Figure 6): Rostov-on-Don-Krasnodar (*LISA* 0.009); Rostov-on-Don - Volgograd (*LISA* 0,006). The most powerful feedback for Rostov-on-Don is from Bataysk (*LISA* - 0.078); Krasnodar - Maykop (*LISA* - 0.0058); Sochi - Maykop (*LISA* -0.004); Astrakhan - Elista (*LISA* -0.001); Volgograd - Volga (*LISA* - 0.01); Sevastopol - Evpatoria (*LISA* -0.0013).

Thus, the presentation of the results of the calculations and their graphic display demonstrate a correlation by the index «population size» in the neighboring cities of the federal district being surveyed. An assessment of the effects of the relationships in the local Moran index of selected areas showed that there was a significant direct relationship between millionaire towns, while feedback was observed relative to the leading city and the nearby city with a population of less than 150 thousand people.

Figure 7. Spatial Moran Dispersion Diagram (migration growth) for the Southern Federal District cities in 2017.



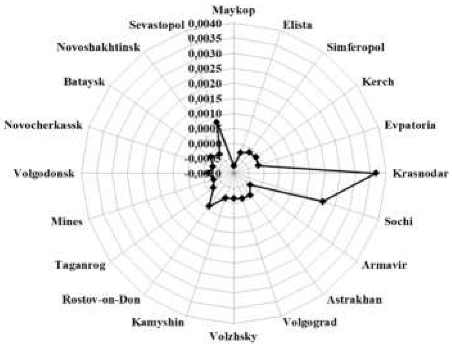
Compiled according to: Regions of Russia. The main socio-economic indicators of cities 2018: stat. compendium / Rosstat. – M., 2018. S, 172-208.

Table 2 Tabular representation of the Moran spatial dispersion diagram for the cities of the Southern Federal District (migration growth) in 2017.

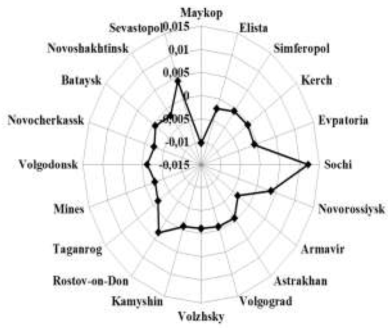
LH				HH			
City	**Z**	**Wz**	**LISA**	**City**	**Z**	**Wz**	**LISA**
Maykop	-0,8996	0,22856	-0,00979	Novorossiysk	0,4086	0,1746	0,00339
Simferopol	-0,2357	0,21181	-0,00238				
Kerch	-0,0770	0,12550	-0,00046				
Evpatoria	-0,3087	0,16345	-0,0024				
Armavir	-0,5715	0,02131	-0,00058				
Bataysk	-0,1323	0,30673	-0,00193				

LL				HL			
City	**Z**	**Wz**	**LISA**	**City**	**Z**	**Wz**	**LISA**
Elista	-0,8589	-0,0608	0,00248	Krasnodar	2,480601	-0,0732	-0,0086
Astrakhan	-0,39786	-0,05192	0,000984	Sochi	2,639734	-0,00133	-0,00017
Volgograd	-0,4540	-1,2377	0,02676	Rostov-on-Don	0,680435	-0,5277	-0,0171
Volzhsky	-0,6225	-0,918	0,027214	Sevastopol	1,615407	-0,0454	-0,0035
Kamyshin	-0,5913	-0,0834	0,002349				
Taganrog	-0,3978	-0,0471	0,000894				
Mines	-0,7136	-0,4278	0,01454				
Volgodonsk	-0,4746	-0,1135	0,00256				
Novocherkassk	-0,5861	-0,2071	0,005782				
Novoshakhtinsk	-0,5027	-0,4071	0,009748				
Compiled from: Regions of Russia. Main socio-economic indicators of cities 2018: Stat. Sat. / Rosstat. - M., 2018.S., 172-208.							

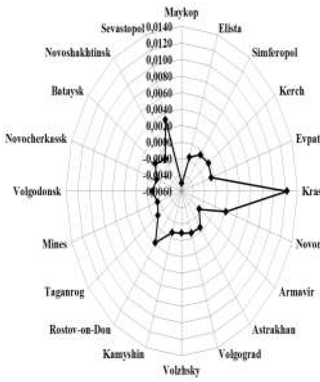
Figure 8 Local Index (*LISA*) Moran in a sample of cities of the Southern Federal District (migration growth) in 2017.



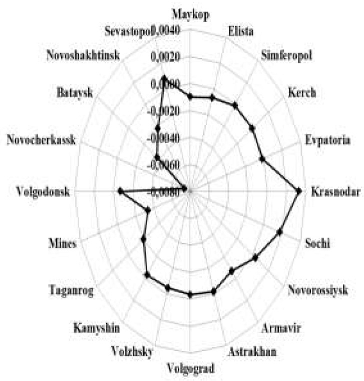
A) Novorossiysk



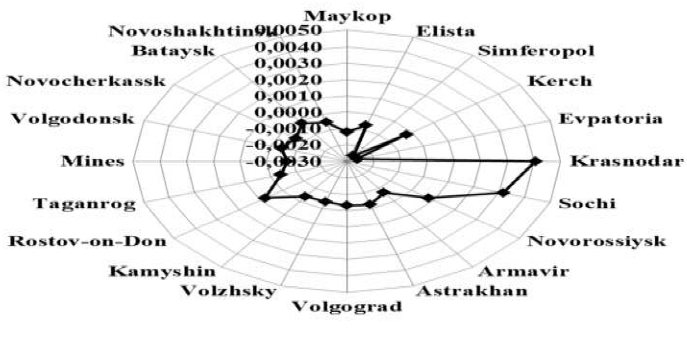
B) Krasnodar



C) Sochi



D) Rostov-on-Don



E) Sevastopol

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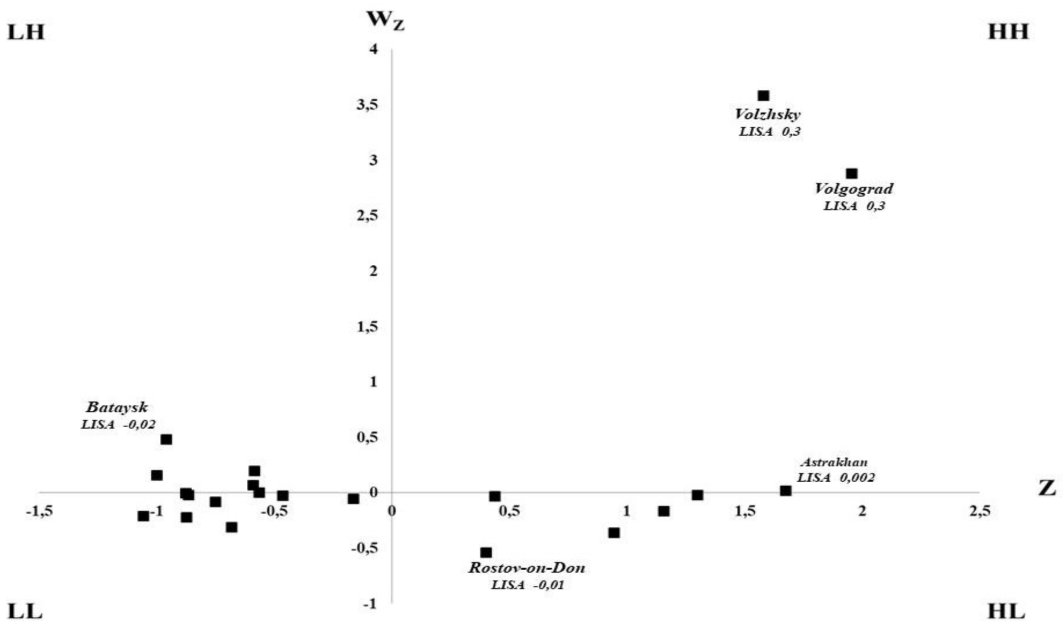
The global Moran index for urban migration in the Southern Federal District yields a value of 0.05, indicating a positive autocorrelation. As shown in figure 7 (square *HH*) and table 2, in the southern Federal district there is one city of Novorossiysk with a relatively high value of the indicator "migration growth", surrounded by territories that also have relatively high values of this indicator. Four cities (square *HL*) have relatively high migration growth, but their neighbors are characterized by a relatively low value of the analyzed indicator. Sixteen cities in the surveyed Federal district have a relatively low level of migration growth, six of which are surrounded by territories with a relatively high value of this indicator (*LH* square).

Analyzing the effects of connectivity of cities in the southern Federal district by the indicator "migration growth", we determined that the strongest direct connections are observed in the leading cities in this indicator located in territorial proximity (Fig.8): Novorossiysk – Krasnodar (*LISA* 0.004); Krasnodar – Sochi (*LISA* 0.01); Rostov-on-don – Krasnodar (*LISA* 0.003), the exception is Sevastopol – Krasnodar (*LISA* 0.004) distance 526 km.

Looking at the feedback from the territories on the rate of migration growth, the strongest effect was found in relation to Mykop. The exception is Sevastopol, for this city strong feedbacks were found in relation to *Y*evpatoria (*LISA* -0.003), Simferopol (*LISA* -0.003).

Thus, the "core" of the "migration growth" indicator was determined in the southern Federal district, which includes Novorossiysk, Krasnodar, Rostov-on-don, Sochi, and Sevastopol. A significant factor for the influx of population to these cities is a favorable warm climate, a relatively high level of economic development, which generally determines the quality of life. Maykop and Yevpatoria experience the greatest «force of attraction» of these cities.

Figure 9 Spatial Distribution Diagram of Moran (per capita product shipped) for cities of the Southern Federal District in 2017



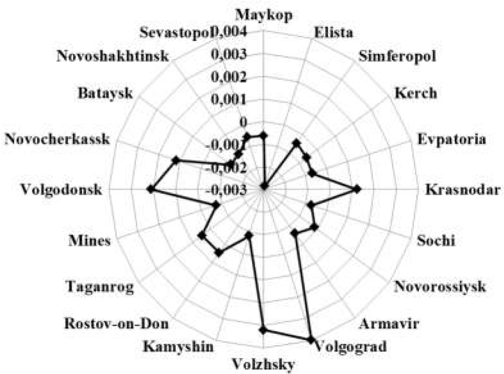
Compiled according to: Regions of Russia. The main socio-economic indicators of cities 2018: stat. compendium / Rosstat. − M., 2018. S, 172-208.

Table 3 Tabular representation of the spatial distribution of Moran for the cities of the Southern Federal District (per capita value of goods shipped) in 2017.

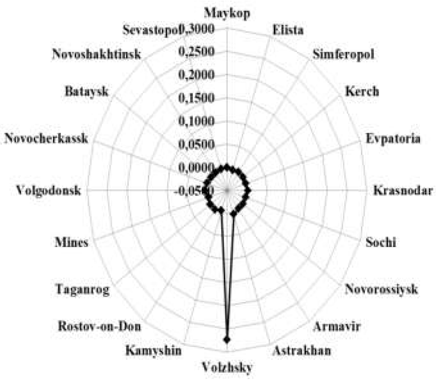
LH				HH			
City	**Z**	**Wz**	**LISA**	**City**	**Z**	**Wz**	**LISA**
Maykop	-0,5662	0,0026	-0,00007	Astrakhan	1,67297	0,0196	0,0015
Elista	-0,9993	0,1628	-0,00775	Volgograd	1,95472	2,8851	0,2685
Kamyshin	-0,5843	0,2012	-0,0056	Volzhsky	1,57865	3,5886	0,26977
Mines	-0,59104	0,0719	-0,0020				
Bataysk	-0,96134	0,4830	-0,02211				

LL				HL			
City	Z	Wz	**LISA**	**City**	**Z**	**Wz**	**LISA**
Simferopol	-0,682	-0,3062	0,0099	Krasnodar	1,15685	-0,161	-0,00
Kerch	-0,752	-0,0812	0,00291	Volgodonsk	1,29925	-0,016	-0,001
Evpatoria	-1,059	-0,2076	0,01048	Novocherkassk	0,94450	-0,358	-0,0161
Sochi	-0,866	-0,0181	0,00075	Rostov-on-Don	0,40068	-0,537	-0,016
Novorossiysk	-0,164	-0,054	0,00042	Taganrog	0,4375	-0,031	-0,0007
Armavir	-0,4649	-0,024	0,00053				
Novoshakhtinsk	-0,8779	-0,0001	0,000001				
Sevastopol	-0,8733	-0,2189	0,00910				
Compiled from: Regions of Russia. Main socio-economic indicators of cities 2018: Stat. Sat. / Rosstat. - M., 2018.S., 172-208.							

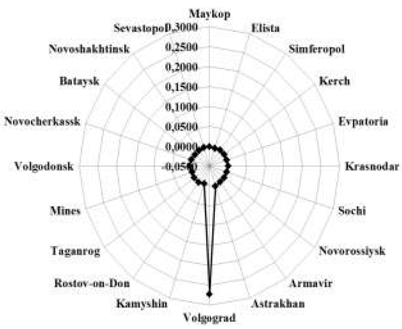
Figure 10 Local Index (*LISA*) Moran in a sample of cities in the Southern Federal District (per capita product shipped) in 2017.



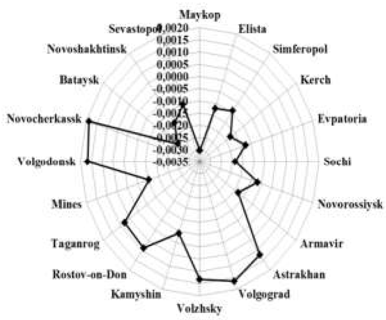
A) Astrakhan



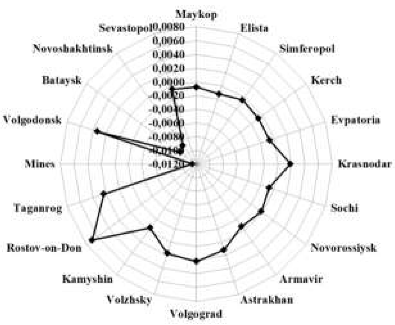
B) Volgograd



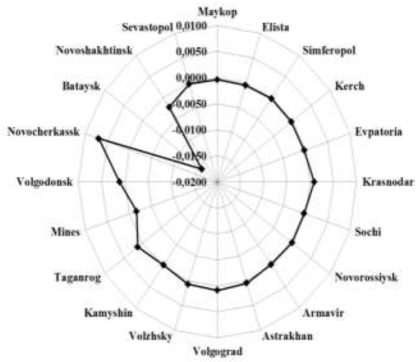
C) Volzhsky



D) Krasnodar



E) Novocherkassk



E) Rostov-on-Don

Compiled according to: Regions of Russia. The main socio-economic indicators of cities 2018: stat. compendium / Rosstat. − M., 2018. S, 172-208.

Spatial autocorrelation assessment based on data from the analysis of per capita shipped output in the cities of the Southern Federal District, indicates that there is a direct relationship between the values of this indicator in the vicinity. Such conclusions make it possible to compare the value of the global Moran index (0.5) with its mathematical expectation (-0.05). According to figure 9, the presence of two leaders Volga and Volgograd is clearly visible. Volzhsky is a major industrial center of the South of Russia, where competitive industries are developing: energy, chemical, mechanical, light and food industries. The level of competitiveness of the Volgograd industry determines the energy complex represented by a number of power plants.

The largest share of the total number of cities is occupied by territories with positive autocorrelation (group LL), which are not influenced by the surrounding territories. The LH squared five cities in different regions of the Southern Federal District.

Considering the connections of cities-leaders of the Southern Federal District according to the index «volume of goods shipped per capita», determined that positive effects manifest in the cities under consideration relative to each other. The data in figure 10 show a significant difference in the extent of backward clump in leading cities. In Volgograd and Volga (fig. 10 «B», «C») when there is a strong direct connection relative to each other, there are no significant opposite inter-territorial effects. Strong inverse spatial effects for city leaders are observed in relation to nearby territories: Krasnodar - Maykop (*LISA* -0.003); Novocherkassk - Shakhty (*LISA* -0.01); Rostov - na-Don - Bataysk (*LISA* -0.01).

5. Conclusion

The study revealed the presence of direct and inverse spatial relationships in the cities of the southern Federal district. There is a negative autocorrelation for the indicator "population", a positive autocorrelation for the indicator "migration growth" and "volume of products shipped per capita". According to the indicator of the volume of products shipped per capita, polarization was revealed: Volgograd and Volzhsky are separated from the rest of the group of cities and have strong direct links relative to each other, while they do not have a significant impact on the surrounding territories.

The strongest direct inter-territorial links were found in the group of leading cities relative to each other. Significant reverse effects are observed for the indicator "migration growth" largely Maikop falls into the zone of influence of the leading cities. Based on a joint analysis of the local Moran index for the indicator "population" and "migration growth", it is possible to assume that the population migrates from this city to Krasnodar and Sochi. Proximity to major cities-leaders in socio-economic parameters contributes to the outflow of population from medium and small cities, increasing differentiation.

To reduce inter-territorial socio-economic differences, it is advisable to develop territories adjacent to the leading cities. Modernization of infrastructure, active social policy, improvement of the quality of life of the population, implementation of programs to attract young professionals will contribute to improving the competitiveness of cities, sustainable development of regions and the country as a whole. The factor that determines the choice of residence of the working-age population is the availability of jobs, the level of remuneration of which meets the requirements of employees. It is important to note that these measures should be carried out throughout the Russian Federation, so as not to increase the unevenness and isolation of individual regions.

The scientific significance of the research consists in the development of theoretical and methodological provisions regarding the assessment of spatial inter-territorial relations, identification of leading cities, and the zone of their influence. In the future, we will continue to study autocorrelation in dynamics, expand the analyzed indicators, and identify spatial and temporal shifts in order to better understand the patterns of spatial development of cities.

The practical significance lies in the possibility of using the results obtained by regional authorities when developing a strategy for the development of cities and regions in terms of identifying production clusters in the region.

6. References

Gabaix X. Zipf's law for cities: an explanation. Quarterly journal of Economics. 1999, vol. 114, no 3, pp. 739-767. doi: 10.1162/003355399556133.

Duranton G. Urban evolutions: The fast, the slow, and the still. The American Economic Review, 2007, no 97, pp. 197-221.

Córdoba J. C. A generalized Gibrat's law. International Economic Review, 2008, no 49, pp. 1463-1468. doi: 10.1111/j.1468–2354.2008.00518.x.

Gabaix X. Zipf's law and the growth of cities. The American Economic Review, 1999, no 89, pp. 129–132.

Eeckhout J., Gibrat's law for (all) cities. The American Economic Review, 2004, no 94, pp. 1429-1451.

Partridge M. D., Rickman D. S., Ali K., Olfert M. R. Employment growth in the American urban hierarchy: long live distance. Journal of Macroeconomics, 2008, no 8(1), pp. 1–8. doi: https://doi.org/10.2202/1935-1690.1627

Lalanne A., Zumpe M. (2015) Gibrat's law, Zipf's law and Cointegration. 2015. [Elektronnyj resurs] URL: https://mpra.ub.uni-muenchen.de/67992/ (data obrashcheniya 18.05.2020).

Trejvish A. Gorod, rajon, strana i mir. Razvitie Rossii glazami stranoveda. – M.: Novyj hronograf, 2009. - 369 s.

Arhipov A.M. Funkcional'naya tipologiya gorodov Central'noj Rossii. Vestnik Akademii, 2010, №2, s.47–51.

Andreev V.V., Lukiyanova V.YU., Kadyshev E.N. Analiz territorial'nogo raspredeleniya naseleniya v sub"ektah Privolzhskogo federal'nogo okruga s primeneniem zakona Cipfa i Gibrata. Prikladnaya ekonometrika, 2017, T. 48, s. 97–121.

Kolomak E.A. Gorodskaya sistema sovremennoj Rossii. – Novosibirsk: Izdatel'stvo IEOPP SO RAN, 2018. – 144 s.

Anselin, L., Getis A. Spatial Statistical Analysis and Geographic Information Systems. The Annuls of Reg&mal Sdence, 1992, vol. 26, rr. 19-33.

Openshaw, S. Some Suggestions Concerning the Development of Artificial Intelligence Tools for Spatial Modelling and Analysis in GIS. In Geographic Information Systems, Spatid M&Uing and Policy EuoluaHon, edited by M. M. Fischer and P. Nijkamp, Berlin: Springer Verlag, 1993, rr. 17-33.

Griffith, D. A. A Spatidy Adjusted ANOVA Model. Geographical Analysis, 1978. vol.10, pp. 296-301.

Griffith, D. A. A Spatially Adjusted N-Way ANOVA Model. Regional Science and Urban Ewwmlcs, 1992, vol. 22, pp. 347-69.

Sokal, R., Oden N., Thomson B., Kim J. Testing for Regional Differences in Means: Distinguishing Inherent from Spurious Spatial Autocorrelation by Restricted Randomization. Geographical Analysis, 1993, vol. 25, pp.199-210.

Anselin, L. Spatid Eccmometrics: Methods and Mo&ls. Dordrecht Kluwer Academic, 1988. Available at: https://link.springer.com/chapter/10.1007/978-94-015-7799-1_1

Anselin, L. Spatial Dependence and Spatial Structural Instability in Applied Regression Analysis. Jornal of Regional Sdence, 1990, vol. 30, pp.185-207.

Bivand RS, Müller W, Reder M. Power calculations for global and local Moran's I. Computational Statistics and Data Analysis, 2009, vol. 53, pp. 2859–2872.

Haining R.P. Spatial autocorrelation and the quantitative revolution. Geographical Analysis, 2009, vol. 41 (4), pp. 364–374.

Li H, Calder CA, Cressie N Beyond Moran's I: Testing for spatial dependence based on the spatial autoregressive model. Geographical Analysis, 2007, vol. 39(4), pp. 357–375.

Tiefelsdorf M. The saddle point approximation of Moran's I and local Moran's Ii reference distributions and their numerical evaluation. Geographical Analysis, 2002, vol. 34(3), pp. 187–206.

Weeks J. R, Getis A, Hill AG, Gadalla MS, Rashed T. The fertility transition in Eqypt: Intraurban patterns in Cairo. Annals of the Association of American Geographers, 2004, vol. 94(1), pp. 74–93.

Moran PAP The interpretation of statistical maps. Journal of the Royal Statistical Society, Series B, 1948, vol. 37(2), pp. 243–251.

Chen Y. New Approaches for Calculating Moran's Index of Spatial Autocorrelation, 2013. Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0068336

Pavlov YU., Koroleva E. Prostranstvennye vzaimodejstviya: ocenka na osnove global'nyh i lokal'nyh indeksov Morana. Prostranstvennaya ekonomika, 2014, № 3, s. 95-110.

Rusanovskij V., Markov V. Vliyanie prostranstvennogo faktora na regional'nuyu differenciaciyu bezraboticy v Rossijskoj Federacii. Problemy prognozirovaniya, 2016, № 5 (158), s. 144-157.

Suvorova A. Razvitie polyusov rosta v Rossijskoj Federacii: pryamye i obratnye effekty. Ekonomicheskie i social'nye peremeny: fakty, tendencii, prognoz, 2019, № 12 (6), s. 110–128. DOI:10.15838/esc.2019.6.66.6

Vakulenko E., (2013) Vvedenie v prostranstvennuyu ekonometriku. M.: NIU VSHE. http://pokrovka11.files.wordpress.com/2013/01/spatial_econometrics.pd