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## Autocorrelation of spatial allocation of funds at the municipality level of Slaskie Voivodship

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**Autocorrelation of spatial allocation of funds at the  
municipality level of Slaskie Voivodship**

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## **Autocorrelation of spatial allocation of funds at the municipality level of Slaskie Voivodship**

**JEL Classification:** *C19;H76; R12*

**Keywords:** *investment funds, municipality, spatial autocorrelation, GIS, Moran's I statistics*

### **Abstract**

**Research background:** Local development is a harmonized and systematic activity of the local community, local authorities and other entities operating in a municipality, aimed at creating and improving the usability of existing municipalities. The primary factor in the local development is investments undertaken by the municipality. The financial reflection of these activities is the amount of investment expenditure. The amount of a municipality's income, its development strategy and the expectations of the local communities influence both the level of investment expenditure and structure, which is diversified both in terms of time and space.

**Purpose of the article:** The aim of the study was to determine the spatial distribution of total funds allocated for investment, and investments in transport and communications in the municipalities of Slaskie Voivodship. Spatial relationship was also determined with the *Moran's I* statistic. The scope of work included creating a spatial database of the examined region at the level of basic local government units, i.e. 167 municipalities. The data were obtained from the studies of official statistics for the years 2008, 2011 and 2014.

**Methodology/methods:** Based on information contained in attribute data sheets, along with the postal codes of municipalities, a spatial database was created in the program ArcView. The analyzed maps were prepared in the GIS program ArcView. For better illustration and reading of detailed data from the prepared maps, the attribute variables were divided into groups using the Jenks method. With it, classes could be determined by comparing the sum of the squares of the differences. The developed classes can also be called a natural border of the division. Based on the prepared spatial database, an analysis was performed with the program R-cran, using *Moran's I* statistics. *Moran's I* statistic determines the differences and similarities between the two objects, and allows analyzing the researched area.

**Findings:** With relation to the analysis of the total funds allocated for investment, the least among the investment periods studied was the year 2008. Noticeable in this period is the largest number of municipalities included in class I (142 municipalities), with the investment range 0 - 6,510,016.26 zloty. The developed spatial distribution shows that municipalities concentrated in the central part of the voivodship make up

an island of high investment funds. These communes are located in the Upper Silesia Agglomeration, with a high population density. High values are also noticeable in large urban centers such as Czestochowa in the north of the voivodship, and Bielsko-Biala in the south.

## **Introduction**

Space is one of fundamental properties of matter since every physical phenomenon takes place in a specific area. Therefore, often space is the subject of many scientific studies in various life spheres: mathematics, biology and even humanities. Economics is a field of science that has sceptically treated the concept of including space in research. It usually ascribes the role of spatial relations analysis to economic geography specialists. It results from a belief which economists shared on the universality of the economic rights regardless the investigated region but also from the lack of methods indispensable to analyse these phenomena. Recognition of a region as an economic space is also essential (Behrens & Thisse, 2007, pp. 457-465, Rey & Janikas, 2006, pp. 67-86). A turning point in economy, the so-called "silent revolution" begun along with the New Economic Geography. The economic geography law suggested by Tobler in 1979 shattered the way of perceiving economy as an independent object which does not interact spatially with neighbours, which was strengthened in the theory of economics. This turning point resulted in formation of spatial development models along with the analysis of spatial distribution of economic activity analysis on the example of activity concentration in agglomerations, transport costs, patterns of localization of companies and the perspective potential of regions (Bosker et al., 2007, pp. 152-169, Sikora et al., 2014, pp. 1317-1326, Szelağ-Sikora, 2009, pp. 39-48).

Autocorrelation is a field of statistics which analyses spatial data, and then deals with description and investigation of spatial phenomena. All phenomena which take place in space are mutually related. Each element influences more or less another neighbouring element. However, one should notice that this phenomenon is reversely proportional to the distance between them. A multi-dimensional nature of the spatial autocorrelation, the so-called need of searching in all directions contrary to the single-direction time trend, is a complicating factor. A wide range of units which may be used in the spatial autocorrelation is another one (distance, neighbours, connections, etc.) (Getis, 2007, pp. 491-496, Anselin, 2007, pp. 450-456). The objective of the paper was to determine spatial distribution of funds designed for all investments and investments concerning transport and communication by the municipalities from Śląskie Voivodeship. Moreover, spatial relations were determined with the use of Moran's *I* statistics.

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## Methodology of research

A database in the form of a calculation sheet was prepared for the purpose of this paper. Data were obtained from the studies prepared by the Main Statistical Office and 167 municipalities of Śląskie Voivodeship were analysed. A municipality was assumed as a reference unit due to a small area of research (voivodeship) and great significance of actions carried out on local levels.

The research concerned expenditures incurred by municipalities on all investments and expenditures on investments incurred for transport and communication. The obtained data refer to 2008, 2011 and 2014. Due to the fact that economy is still developing and that data similar to the present situation in a given municipality must be analysed, selection of years close to each other was justified.

Based on the information included in the prepared numerical database with codes of municipalities a spatial database was prepared in ArcView program. Three various file extensions describe the spatial database:

- extension \*.shp due to which we define the investigated area,
- extension \*.shx which serves for ascribing suitable identifiers and combining surrounding data,
- extension \*.dbf which presents spatial database with the list of previously accepted variables.

The analysed maps were prepared in GIS ArcView program and for a better preview and readout of particular data from the prepared maps Jenk's method was applied (table 1).

**Table 1.** Classes of natural borders of division according to Jenk's method

| Class | Value       | Shade         |
|-------|-------------|---------------|
| I     | very low    | the brightest |
| II    | low         | bright        |
| III   | average     | medium        |
| IV    | high        | dark          |
| V     | the highest | the darkest   |

Source: Sikora et al., 2014, pp. 1317-1326

## Global Moran's *I* statistics

Moran's *I* statistics is used for testing global spatial relations and gives a possibility of determination whether there is a spatial effect of agglomeration. Values of Moran's *I* statistics are within -1 to 1.

The described statistics may be determined with the two following formulas:

$$I = \frac{\sum_i \sum_j w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{s^2 \sum_i \sum_j w_{ij}} \quad (1)$$

$$\frac{1}{n} \sum_i (x_i - \bar{x})^2 \quad (2)$$

where:

$x_i$  – observation in *i* region,

$\bar{x}$  - average from all investigated regions,

*n* - number of regions,

$w_{ij}$  – element of the spatial matrix of weights *W*.

Characteristic of the obtained results of global Moran's *I* statistics:

- if the value of Moran's *I* statistics is within (0.1>, namely  $I > 0$  then a positive spatial autocorrelation takes place, values of close observations are similar,
- if the value of Moran's *I* statistics is within (-1.0, <-1.0), namely  $I < 0$  then a positive spatial autocorrelation takes place, values of close observations are similar,
- if the value of Moran's *I* statistics is zero, namely  $I = 0$ , then in the investigated space values of observations are randomly distributed (Sikora, 2009, pp.217-227).

### Matrices of spatial weights

Matrices of spatial weights are a basic element of spatial analyses. For the research the most often applied type of matrix was assumed, namely a matrix of neighbourhood constructed based on the criteria of a common border. Thanks to this analysis, we are able to obtain the best reflection of the closeness of the analysed objects in the investigated space. Matrices of neighbourhood weights may be divided into the following types:

- B type matrix - basic binar zero-one matrix,
- W type matrix - of the first row standardized with rows,
- C type matrix - generally standardized,
- U type matrix - divided into the number of neighbours,
- S type matrix - stabilizing variations.

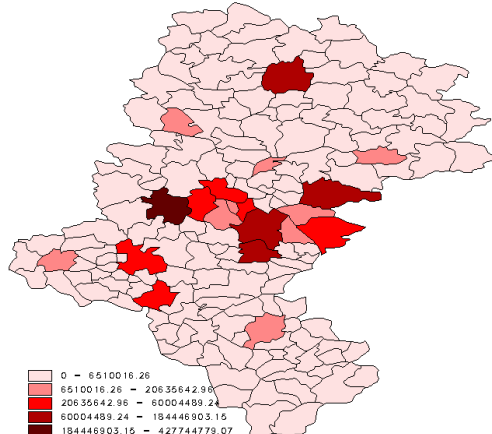
Elements of weight matrix assume the following values:

- $w_{ij} = 1$ , when  $i$  object neighbours with  $j$  object,
- $w_{ij} = 0$ , when  $i$  object does not neighbour with  $j$  object,
- $w_{ij} = 0$  diagonal elements of the matrix.

## Results and discussion

167 municipalities from Śląskie Voivodeship were analysed with division into two categories of variables. Figure 1, 2 and 3 present a spatial distribution of expenses on all investments in the years 2008, 2011 and 2013 and figure 4, 5 and 6 present a spatial distribution of means designated for the transport and communication investments also in the above-mentioned years.

### Means designated for all investments



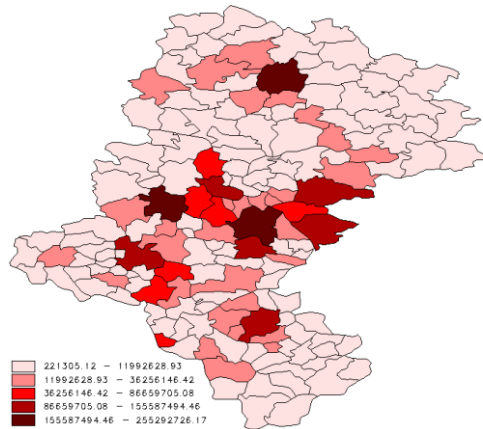
**Figure 1.** Spatial distribution of expenses designated for investments in 2008 in municipalities of Śląskie Voivodeships

Source: Author's own study

147 municipalities were marked with a colour, which is 88% of the total investigated area. The measure of development of the first class is within PLN 0 – 6510016.26. While observing figure 7 we may also notice that along with the increase of the class, the number of municipalities in a given class drops.

In particular classes we respectively have:

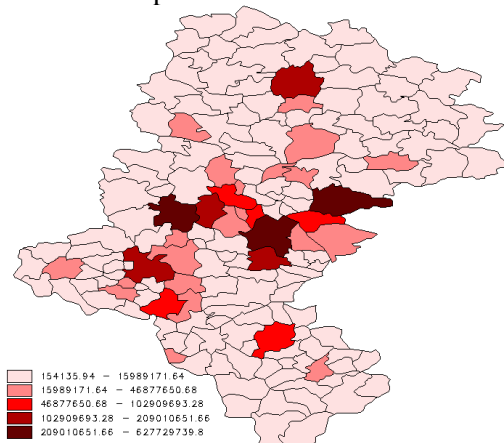
- in class I - 147 municipalities, which is 88%,
- in class II - 9 municipalities, which is 5.39%,
- in class III - 6 municipalities, which is 3.59%,
- in class IV - 4 municipalities, which is 2.40%,
- in class V - 1 municipality, which is 0.60%.



**Figure 2.** Spatial distribution of expenses designated for investments in 2011 at the level of municipalities of Śląskie Voivodeship

Source: Author's own study

In 2011 we may observe a decisive raising trend of the funds allotted for investments by municipalities in comparison to 2008. A disproportion between municipalities which are in the lowest class and those in the highest classes has decreased. In the lowest class, there were 120 municipalities which constitutes 71% of the investigated area with PLN 221305.12 – 11992628.93 The highest increase in the number of municipalities (over 10%) in comparison to 2008 was reported in class II.



**Figure 3.** Spatial distribution of expenses designated for investments in 2014 at the level of municipalities of Śląskie Voivodeship

Source: Author's own study



The spatial analysis of data for 2014 shows that still there is the highest number of municipalities which allot the lowest amounts of funds for investments. These are precisely 134 municipalities and their aggregate measure was within PLN 154135.94 – 15989171.64. The number of municipalities from the I class is visible. We may notice a clear decrease of funds designated on the investments in the municipalities of Częstochowa and Bielsko-Biała provinces. Investments in the municipalities of Śląsk agglomeration: Katowice, Gliwice and Dąbrowa Górnicza were at a constant high level.

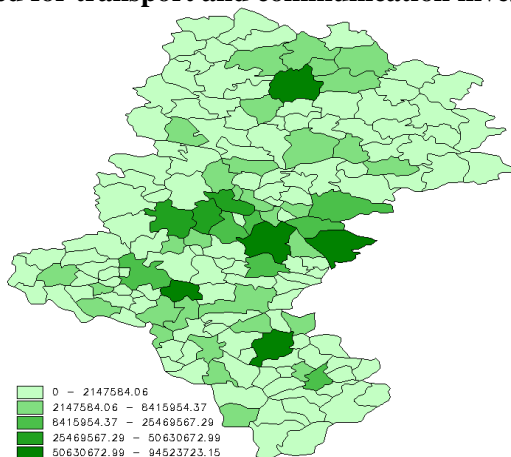
**Table 2.** Characteristics of investigated municipalities on account of indicator of funds allotted to all investments in municipalities of Śląskie Voivodeship

| Classes | Number of poviats in a given class |      |      | Participation of poviats (%) |       |       |
|---------|------------------------------------|------|------|------------------------------|-------|-------|
|         | 2008                               | 2011 | 2014 | 2008                         | 2011  | 2014  |
| I       | 147                                | 120  | 134  | 88                           | 71.85 | 80.24 |
| II      | 9                                  | 31   | 21   | 5.39                         | 18.56 | 12.57 |
| III     | 6                                  | 7    | 5    | 3.59                         | 4.19  | 2.99  |
| IV      | 4                                  | 6    | 4    | 2.40                         | 3.59  | 2.40  |
| V       | 1                                  | 3    | 3    | 0.60                         | 1.80  | 1.80  |

Source: Author's own study

To sum up, the spatial distribution shows that municipalities located in the central part of the voivodeship allot the highest amount of funds on investments. It results mainly from high urbanization, which we may observe in the Upper Sillesia conurbation.

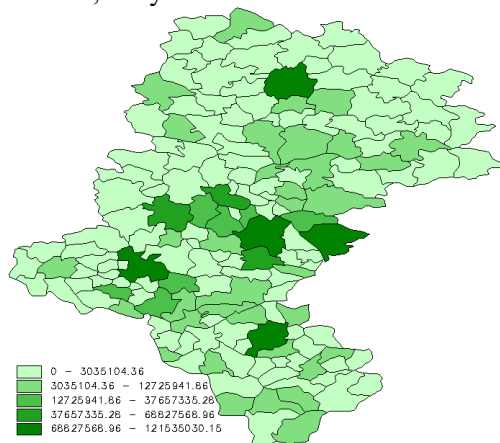
### Funds designated for transport and communication investments



**Figure 4.** Spatial distribution of funds designated for transport and communication investments in 2008 in Śląskie Voivodeships

Source: Author's own study

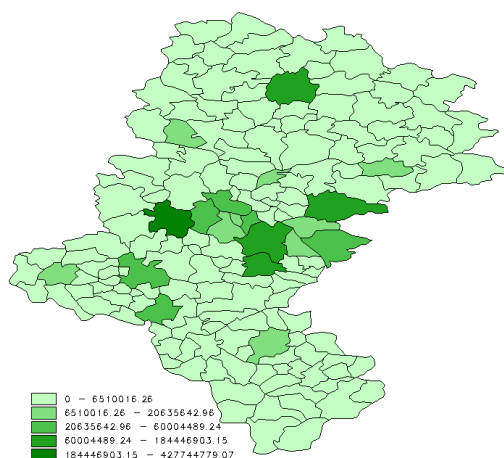
Spatial analysis of funds allotted for transport and communication investments in 2008 allows a statement that there are high discrepancies between the investigated municipalities. It is confirmed by the fact that municipalities which have the highest inputs on the investments are represented only by 5 companies and in the class I (the lowest) and their value is as much as 120 municipalities. The highest expenditures for transport and communication were reported in the following municipalities: Bielsko-Biała, Częstochowa, Katowice, Żory and Jaworzno.



**Figure 5.** Spatial distribution of funds designated for transport and communication investments in 2011 in municipalities of Śląskie Voivodeships

Source: Author's own study

On the presented map we can also notice that the second class was left by the municipalities located to the north of Częstochowa, namely: Kłobuck, Mykanów, Rędziny, Kłomnice and Mstów. On the south of the voivodeship, the spatial analysis proved the increase of expenses in the following municipalities: Milówka, Węgierska Góra and Ujszoły.



**Figure 6.** Spatial distribution of funds designated for transport and communication investments in 2014 at the level of municipalities of Śląskie Voivodeships

Source: Author's own study

In 2014 we may observe a considerable increase of municipalities which are in class I. In the analysed period in the group of municipalities with the biggest expenses on the transport and communication investments there were 147 municipalities which constitutes as much as 88% of the investigated group. The biggest changes of the spatial distribution in comparison to 2008 and 2011 may be observed in municipalities which previously were in the second class. Undoubtedly, the increase of the scope for the second class has a great impact on the state of affairs.

**Table 3.** Characteristics of the investigated municipalities on account of the indicator of funds allotted for transport and communication investments in the municipalities of Śląskie Voivodeship

| Classes | Number of poviats in a given class |      |      | Participation of poviats (%) |       |       |
|---------|------------------------------------|------|------|------------------------------|-------|-------|
|         | 2008                               | 2011 | 2014 | 2008                         | 2011  | 2014  |
| I       | 120                                | 117  | 147  | 71.86                        | 70.06 | 88.02 |
| II      | 32                                 | 35   | 9    | 19.16                        | 20.96 | 5.39  |
| III     | 7                                  | 7    | 6    | 4.19                         | 4.19  | 3.59  |
| IV      | 3                                  | 3    | 4    | 1.79                         | 1.79  | 2.40  |
| V       | 5                                  | 5    | 1    | 2.99                         | 2.99  | 0.60  |

Source: Author's own study

From the spatial analysis of the funds allotted for the transport and communication investments in Śląskie Voivodeship in 2008, 2011 and 2014 we may conclude that between the first two investigated periods there were no considerable differences. However, 2014 presents completely different values. In 2014 in comparison to the previous year, a decisive decrease of municipalities of the II and IV class was reported. However, attention should be paid to the fact that in 2014, measures of scopes of particular classes increased largely and it resulted from great financial inputs in Gliwice municipality. In 2008 and 2011 transport and communication investments were distributed into a greater number of municipalities mainly on account of the construction of A4 highway and many transportation hubs and access roads on the territory of Śląskie Voivodeship.

### **Spatial relations based on Moran's I global statistics**

Formulation of analysis was initiated from the matrix of weights of the basic which uses a relation of closeness of objects by means of a common border. Results of relations were presented in table 7. 10 groups of relations were separated from the space of Śląskie Voivodeship. One object had only one neighbour and it was a municipality with the identification number 142 (Koszarawa), it is a municipality of Beskid Żywiecki the most protruding to the south east of the voivodeship and cutting into the area of Małopolskie Voivodeship. The number of relations in the so defined matrix was 892 and it was 3.2 % of all possible interactions.

Characteristic of the first row matrices type "B" for the set of 167 municipalities of Śląskie Voivodeship:

- number of regions: 167,
- number of non-zero relations: 892,
- interest of non-zero relations: 3,19,
- average number of relations: 5,35,
- object with only one neighbour: 142,
- object with the highest number of relations; 85.

**Tabela 4.** Number of relations of spatial objects

|                      |   |   |    |    |    |    |    |   |   |    |
|----------------------|---|---|----|----|----|----|----|---|---|----|
| Number of neighbours | 1 | 2 | 3  | 4  | 5  | 6  | 7  | 8 | 9 | 11 |
| Number of objects    | 1 | 2 | 17 | 42 | 30 | 34 | 24 | 9 | 7 | 1  |

Source: Author's own study

Results based on the matrix of weights with the criterion of mutual border for the set of municipalities of Śląskie Voivodeship were placed in table 8. Results of the spatial analysis based on Moran's  $I$  statistics confirm that the biggest number of funds allotted for all investments and in the transport and communication department in the municipalities of Śląskie Voivodeship can be observed in 2011. The increase of the value of the index of Moran's  $I$  statistics between 2008 and 2011 informs on the convergence process which takes place. In case of the period between 2011 and 2014 the divergence process is noticeable.

**Table 5.** Spatial analysis for synthetic indicator determined for allotted funds for all investments and for transport and communication based on Moran's  $I$  global statistics of the set ( $\Omega_s$ )

| Type of weights  | Year 2008 |                       | Year 2011 |                       | Year 2014 |                       |
|--|-----------|-----------------------|-----------|-----------------------|-----------|-----------------------|
|  | $I$       | level of significance | $I$       | level of significance | $I$       | level of significance |
| Funds for all investments in municipalities                              |           |                       |           |                       |           |                       |
| Weights of neighbourhood according to joint border type B                | 0.278     | $p < 0.05$            | 0.464     | $p < 0.05$            | 0.333     | $p < 0.05$            |
| Funds allotted for investments in transport and communication department |           |                       |           |                       |           |                       |
| Weights of neighbourhood according to joint border type B                | 0.451     | $p < 0.05$            | 0.493     | $p < 0.05$            | 0.207     | $p < 0.05$            |

Source: Author's own study

In case of variables describing funds allotted to all investments and the transport and communication investments there is a spatial autocorrelation in all time intervals. Autocorrelation has a positive nature. It means that objects with similar values of measure of funds allotted for investments tend to group together.

## Conclusion

Spatial analyses were made based on two variables - funds allotted for all investments and funds for transport and communication investments. Data from 2008, 2011 and 2014 were accepted for the research. The research area covered all 167 municipalities of Śląskie Voivodeship. The tests which were carried out enabled observation of considerable discrepancies between the municipalities which are on rural areas and urban municipalities.

The spatial distribution shows that municipalities grouped in the central part of the voivodeship form an island of high values of funds allotted for investments. These municipalities are in Górny Śląsk agglomeration with a high population density. High values are also notable in big urban centres such as Częstochowa in the north of the voivodeship and Bielko-Biała in the south. The analysis which was carried out unanimously states that there is a great disproportion in the funds allotted to investments between municipalities which are in rural areas and city municipalities. Of course, there are exceptions, which occur mainly in rural municipalities which neighbour with big urban centres. Municipalities focused around Częstochowa and Żory are an example in the research concerning transport and communication investments for 2008.

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