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**The problem of the inclusion of
spatial dependence within the TOPSIS method**

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Toruń, Poland 2015

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The problem of the inclusion of spatial dependence within the TOPSIS method

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Abstract: According to Tobler's first law of geography, one of the key issues in doing the regional research is considering spatial location. Therefore, the article presents a proposal for modifying the TOPSIS method, which allows the spatial dependence to be considered in the research. The composite index calculated by means of the modified TOPSIS method allows to determine the trend in the level of the development of the phenomenon under study, assuming the impact of the spatial mechanisms. The TOPSIS method defined in that way has been applied in the spatial analysis of the situation on the labour market in Poland.

Introduction

The content The economic research has increasingly dealt with the problem of the occurrence of spatial dependence and with the consideration of this dependence in analyses being conducted. On the one hand, this fact results from the popularisation of the methods applied in spatial econometrics as well as in spatial statistics; on the other hand, it is also impacted significantly by the availability of software that allows carrying out tests on spatial autocorrelation and estimating parameters of spatial econometric models (see: Haining 2003, Arbia 2006, Bivand, Pebesma and Gómez-Rubio 2008, Ward and Kristian 2008, LeSage and Pace 2009,

Fischer and Getis 2010, Gelfand et al. 2010, Griffith and Paelinck 2011, Plant 2012).

The presence of positive spatial dependence is embedded in the majority of economic phenomena resulting from the nature of the functioning of economic systems. This property is expressed as Tobler's first law of geography, where it is assumed that the level of interaction between regions decreases along with the increase in the distance between them (see: Tobler 1970). The problem of spatial dependence is crucial, since it means the possibility of the formation of the level of phenomena depending upon which spatial location is being considered. Therefore, failure to consider the existing spatial dependence for the analysed phenomena while conducting economic research can lead to cognitive errors (see: Cliff and Ord 1973; Paelinck and Nijkamp 1975, Paelinck and Klaassen 1979; Ripley 1981; Anselin 1988; Griffith 1988; Arbia 1989, Haining 1990, Cressie 1993).

The composite index also known as 'taxonomic measure of development' (see: Hellwig 1972, Hwang and Yoon, 1981)¹ is a commonly used tool in economic research. Taxonomic measure of development (TDM) allowing for evaluation and ranking of objects due to the level of the development of the analysed phenomenon. In order to use this composite index, the examined economic phenomenon is broken down to a group of economic aspects and each of them describes a different part of the phenomenon. Then, for each aspect a set of variables is selected², characterizing the aspect and allowing its description. In the last step, based on the accepted variables, the synthetic index is calculated, which takes into account the effect of all the economic determinants of the phenomenon under study and allows a synthetic assessment of the level of its development to be made.

In the case where the objects evaluated are regions, economic phenomena are generally characterized by the presence of spatial dependence. Therefore, it seems necessary to take into account this dependence in the construction of the taxonomic measure of development.

The spatial taxonomic measure of development (sTMD) extended with spatial properties would allow considering the impact of spatial mechanisms while assessing regions. These mechanisms are responsible for

¹ In subject literature concerning the issue of the use of the TOPSIS method in MADM (multiple criteria decision making problem), the taxonomic measure of development is defined as relative closeness to the ideal solution.

² In subject literature the variables are also referred to as 'indicators' or 'determinants', and in the case of MADM, they are referred to as 'criteria' or 'attributes'.

mutual interactions between regions. Thus they contribute to the maintaining of the current situation of regions, or they affect significantly changes in their situation.

Therefore, the proposal to use the spatial taxonomic measure of development in research is complementary to the use of TMD. The use of the taxonomic measure of development allows the assessment of the current situation of the analysed system of regions. The use of sTMD, however, gives the possibility to extend the results with the conclusions on the trend in the level of the development of regions relative to the phenomenon under study.

The purpose of this article is to take into account the issue of the consideration of spatial dependence within the TOPSIS method. The outcome of the implementation of the proposal made will be the construction of the spatial taxonomic measure of development (sTMD). The measure proposed in the article will be applied in the analysis of the situation on the labour market in Poland. The study will be carried out for the territorial composition of 66 subregions (NUTS 3 level)³ as of 2013.

The construction of the spatial taxonomic measure of development with the use of the TOPSIS method

The research on the *scale problem* was started with raising the issue of research in the form of regression analysis for selected economic variables. The paper considers The concept of the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) was presented in a work by Hwang, Yoon (1981). This method is used for solving a multiple criteria decision making problem (MADM). This means that TOPSIS is the method for order alternatives by similarity to an ideal solution. The TOPSIS method is the extension of the taxonomic method proposed by Hellwig (1972)⁴. In the case of Hellwig's method for calculating the value of the

³ According to the nomenclature of the European Union in Poland, as a member state, the effective administrative division is NUTS (Nomenclature of Territorial Units for Statistics). There are three regional levels, NUTS1 (regions), NUTS 2 (voivodships) and NUTS 3 (subregions). Then two levels are distinguished at the local level. The territorial composition NUTS 4 (districts and city districts) and NUTS 5 (municipalities).

⁴ The method proposed by Hellwig was a tool for the evaluation of objects relative to the level of the development of the phenomenon under study. The TOPSIS method, in turn, has been proposed in the context of MADM understood as a tool for selecting the best alternative.

composite index (taxonomic measure of development), only the distance of objects from the pattern of development is considered. However, the TOPSIS method takes into account the distance of objects both from the pattern and from the anti-pattern.

In the present article the TOPSIS method will be considered in the context of determining the taxonomic measure of development for the needs of the assessment of economic objects relative to the level of development of the phenomenon under study. Therefore, the use of the TOPSIS method will allow the evaluation of objects, working out the ranking of objects and, then, grouping these objects into classes. The examples of work using the TOPSIS method in the context of research understood in the aforementioned way is Balcerzak, Pietrzak (2014).

It should be emphasised that the concept of the taxonomic measure of development is a useful and universal tool that can be applied in economic research. The major advantage of this concept is its cognitive value while explaining economic reality and the flexibility of its application. This tool can be used to analyse the most of economic phenomena. Additionally, the subject of analysis can be any economic object considered in the context of the economic problem under study. There are, however, two main limitations on the use of the taxonomic measure of development in economic research. The first limitation is the availability of statistical data, and the other is scientific knowledge possessed and the researcher's experience, which should allow precisising adequately the analysed phenomenon and expressing its multi-aspect nature by means of simple economic phenomena. In the case of the first limitation, the cognitive value of the tool is frequently not utilized fully, or it cannot be applied at all. As regards the second limitation, the cognitive value of the tool in explaining economic reality is used inadequately, which could result in serious cognitive errors.

Identification of spatial dependence for selected variables compels their consideration while constructing the taxonomic measure of development. Since each variable represents a different aspect of the economic reality, therefore, it is essential that the level of spatial dependence, which occurs with varying intensity, should be examined separately for each of them. In order to identify and assess the strength of spatial dependence, the spatial autoregressive model SAR can be applied (see: Anselin 1988, LeSage Pace 2009)⁵. In addition to the impact of explanatory variables, this model takes into account also the spatial lag of

⁵ Moran I statistic is most commonly used in testing spatial autocorrelation of selected variables (see: Moran 1950, Clif and Ord 1973,1981).

the dependent variable \mathbf{WY} . Spatial lag describes the average impact of the neighbouring regions⁶ on the value of the dependent variable in the selected region.

The SAR model with one explanatory variable \mathbf{X} is defined by the following formula (1):

$$\mathbf{Y} = \rho \mathbf{WY} + \beta_1 \mathbf{X} + \varepsilon. \quad (1)$$

$$\mathbf{V}(\mathbf{W}) = (\mathbf{I} - \rho \mathbf{W})^{-1}, \quad (2)$$

$$\mathbf{Y} = \mathbf{V}(\mathbf{W})\beta_1 \mathbf{X} + \mathbf{V}(\mathbf{W})\varepsilon, \quad (3)$$

$$\mathbf{V}(\mathbf{W}) = \begin{bmatrix} v_{11} & \cdot & \cdot & v_{1n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ v_{n1} & \cdot & \cdot & v_{nn} \end{bmatrix}, \quad (4)$$

$$\frac{\partial E(Y_i)}{\partial x_j} = v_{ij} \beta_1 \quad (5)$$

where \mathbf{Y} is the vector of the dependent variable, \mathbf{X} is the vector of the explanatory variable, ρ is the coefficient of the spatially lagged dependent variable, \mathbf{W} is the standardized spatial weight matrix, β_1 is a structural parameter of the model, and ε is the disturbance term, $\mathbf{V}(\mathbf{W})$ is the matrix of potential impact.

On the basis of formula 2, the value of potential impact v can be calculated for all pairs of regions. The elements v_{ij} of the matrix $\mathbf{V}(\mathbf{W})$ express the potential impact of the region j on the region i ⁷. The key issue here is the choice of the spatial weight matrix, because the potential impact is determined based on the elements of this matrix. It should be noted, however, that in contrast to the classical linear regression model the impact of determinants varies depending on the considered regions (see: Ward and Kristian 2008, LeSage and Pace 2009, Pietrzak 2013). The average impact

⁶ The neighbourhood of regions is expressed by means of a spatial weight matrix \mathbf{W} . However, a standardized spatial contiguity matrix is most commonly used while doing economic research. In the case of this matrix, the neighbourhood is determined on the basis of the criterion of having a common border between the regions (see: Anselin 1988). In addition, the matrix is standardized in the way that the row elements sum to one.

⁷ Matrix of potential impact $\mathbf{V}(\mathbf{W})$ is not symmetric. This means that the potential impact of region i on region j and of region j on region i may vary.

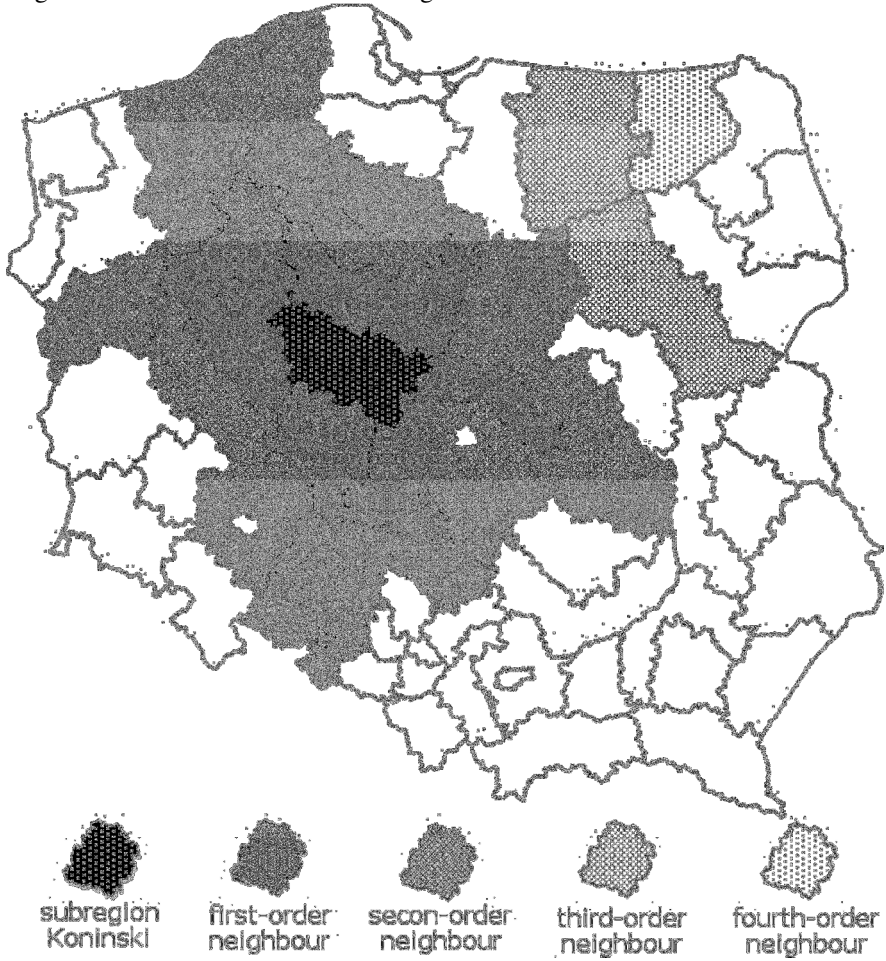
resulting from the change of the explanatory variable in the region j into the dependent variable in the region i can be defined by formula (5). According to this formula, depending on the choice of regions i and j , the value of the structural parameter β_1 is weighted by the value of the potential impact v_{ij} .

The assumption of the existence of spatial dependence means that in the evaluation of the phenomenon in the selected region, in addition to the values of the variables in this region, one should also take into account the value of variables from other regions. In the case of the identification of spatial dependence, variables must be converted in such a way as to take into account possible interactions between regions. The resulting new variables will carry additional information about the trends in the spatial formation of the studied phenomenon. It is assumed that spatial dependence should not change significantly over time, since it results from the impact of a set of spatial mechanisms. A combination of these mechanisms creates a spatial structure, in which one can observe the impact of economic, historical, cultural or sociological factors. Given the persistence of spatial dependence, it is likely that over a few years the established trend will prove to be facts. It should be emphasized that the situation in the regions is also dependent on regional policy. Spatial mechanisms can have either a positive impact - supporting regional policies pursued, or negative - weakening them significantly. The situation in regions is eventually influenced by the starting position of the regions, regional policies pursued as well as the spatial mechanisms. The taxonomic measure of development may be helpful in assessing the initial situation of regions, and the spatial taxonomic measure of development in identifying trend in the level of development of the phenomenon studied. This trend results from both the current situation of the phenomenon and from the spatial dependence.

In order to demonstrate the formation of the potential impact v_{ij} , the matrix $\mathbf{V}(\mathbf{W})$ was considered for the territorial composition of 66 subregions in Poland (NUTS 3 level). This territorial composition is presented in Figure 1. Then, the Koninski subregion was selected arbitrarily based on which the potential impact from the other regions was discussed. Therefore, Figure 1 highlights the Koninski subregion for which additional first-order and second-order neighbourhood subregions are marked⁸.

⁸ The standardized spatial contiguity matrix \mathbf{W} was assumed in the research. In the case of the criterion contiguity, regions are adjacent in the sense of first-order neighbourhood, if they have a common border. The regions are adjacent in terms of second-order neighbourhood, if they have a common first-order neighbour.

Figure 1. Territorial composition of 66 subregions in Poland (NUTS 3) and neighbourhoods for the Koninski subregion.



Source: Authors' compilation.

Table 1. Potential impact between subregions

Subregion <i>j</i>	Potential impact v_{ij}	Order of the neighbourhood
Koninski	1,130	0
Wloclawski	0,192	1
Sieradzki	0,203	1
Skierniewicki	0,195	1
Kaliski	0,200	1
Pilski	0,214	1
Poznanski	0,203	1
Ciechanowsko-plocki	0,060	2
Radomski	0,014	2
Warszawski zachodni	0,035	2
Nyski	0,054	2
Opolski	0,032	2
Czestochowski	0,030	2
City Poznan	0,028	2
Koszalinski	0,032	2
Slupski	0,036	2
Leszczynski	0,089	2
Gorzowski	0,039	2
Lodzki	0,048	2
Piotrkowski	0,058	2
Wroclawski	0,054	2
Bydgosko-torunski	0,029	2
Grudziadzki	0,067	2
Ostrolecko-siedlecki	0,010	3
Olsztynski	0,009	3
Elcki	0,003	4

Source: Authors' compilation.

The matrix of potential impact $\mathbf{V}(\mathbf{W})$ was determined according to formula 2, assuming the coefficient of the spatially lagged dependent variable ρ of 0.7⁹. The results are shown in Table 1¹⁰, where the second

⁹ The author assumes arbitrarily the coefficient of the spatially lagged dependent variable value of 0.7, which means that there is strong spatial dependence.

column presents the value of the potential impact v of selected subregions j (column 1) on the Koninski subregion i . The third column, in turn, shows the order of the neighbourhood for selected subregions to the Koninski subregion.

The highest value of the potential impact v_{ij} is obtained in the situation where both the region i and the region j constitute the Koninski subregion. The resulting value is greater than one (1.130). That means that if there is spatial dependence, the impact resulting from the change of an explanatory variable into the dependent variable within the same region is greater than the value of structural parameter β_1 (formula 5). Then, along with the increase in the order of the neighbourhood the level of potential impact decreases. In the case subregions that are first order neighbours of the Koninski subregion, the average value of the potential impact v_{ij} is 0.201. For the second order neighbours of the Koninski subregion the average value of the potential impact decreases significantly to the level of 0.044. However, in the case of the third order (or higher) neighbours of Koninski subregion, potential impact is close to zero.

Finding statistically significant spatial dependence for selected variable X_k indicates the need for its transformation to reflect this dependence in the values of the spatial taxonomic measure of development. To transform the variable X_k the matrix of potential impact $\mathbf{V}(\mathbf{W})$ can be used. To this end, for each variable X_k the matrix $\mathbf{V}(\mathbf{W})$ needs to be calculated (Formula 2) based on a SAR model described by the following formula:

$$\mathbf{X}_k = \rho \mathbf{W} \mathbf{X}_k + \varepsilon. \quad (6)$$

The finding of the matrix $\mathbf{V}(\mathbf{W})$ will allow the consideration of the potential spatial interaction between regions for the variable X_k using the following transformation:

$$\mathbf{Z}_k = (\mathbf{I} - \rho \mathbf{W})^{-1} \mathbf{X}_k = \mathbf{V}(\mathbf{W}) \mathbf{X}_k. \quad (7)$$

The transformation of the variable X_k consists in adding the value of a variable from other regions to the value of this variable representing a

10 Values v_{ij} presented in Table 1 are only a part of the matrix of potential impact $\mathbf{V}(\mathbf{W})$. From the matrix $\mathbf{V}(\mathbf{W})$ only one row corresponding to the Koninski subregion was selected. Then subregions were selected due to the order of neighbourhood. All first-order and second-order neighbours of the Koninski subregion were selected. In addition, two adjacent third-order and one fourth-order neighbours of the the Koninski subregion were selected in order to demonstrate the formation of the potential impact of v_{ij} in this case. Presenting all of the elements of the matrix $\mathbf{V}(\mathbf{W})$ would require the presentation of a table with 66x66 in dimension.

selected region i . However, the values of the variable X_k from other regions will be weighed according to the rule that the greater the potential impact of the region j on the region i , the greater the extent will be considered.

In the case of spatial dependence statistically insignificant, the value of the variable should remain unchanged. Consequently, the value of the spatial taxonomic measure of development in the chosen region i will be impacted only by the value of the variable corresponding to this region.

The procedure for calculating the spatial taxonomic measure of development using the TOPSIS method can be summarized in the following steps:

1. Determining the research problem and the selection of a phenomenon for analysis in the context of the problem undertaken.
2. Establishing a set of objects O_1, O_2, \dots, O_m and the choice of the variables X_1, X_2, \dots, X_n describing the phenomenon analysed.
3. Testing spatial autocorrelation for each variable X_k using Moran test.
4. Taking into account the spatial dependence by transforming the variables.

a) In the case of finding statistically significant spatial dependence for selected variable X_k , the first step to be carried out is estimating the coefficient of the spatially lagged dependent variable ρ of the SAR model defined by formula (6). Then we should calculate the matrix of the potential impact $\mathbf{V}(\mathbf{W})$, which will allow the transformation of the variable X_k according to formula (7).

b) In the case of finding a statistically insignificant spatial dependence for the selected variable X_k , it is not transformed.

5. Determining the nature of the transformed variables Z_k (stimulant Z_k^s , destimulant Z_k^d ¹¹) and conversing destimulants to stimulants following the formula

$$Z_k^s = 1/Z_k^d. \quad (8)$$

6. Normalization of all variables (stimulants) Z_k according to the formula

$$Z_k^N = \frac{Z_k - m_k}{s_k} \quad (9)$$

where m_k, s_k are mean and standard deviation of the variable X_k .

7. Establishing for each variable Z_k^N the pattern of development W_k as the maximum value of the variable Z_k^N for a set of objects O_1, O_2, \dots, O_m and the anti-pattern of development AW_k as the minimum value¹².

¹¹ ‘Stimulants’ are variables that stimulate the development of the phenomenon under study. ‘Destimulants’ are those variables that inhibit that development (see: Hellwig 1972).

8. Determining for each object O_s the Euclidean distance d_s^W from the patterns and the Euclidean distance d_s^{AW} from the anti-patterns.

9. The values of the spatial taxonomic measure of development sTMD for each object O_s are obtained through the calculation of the measure considering the proximity to the pattern and the distance from the anti-pattern, which can be described by the following equation

$$sTMD_s = \frac{d_s^{AW}}{d_s^{AW} + d_s^W} \quad (10).$$

The values of the spatial taxonomic measure of development sTMD determine the trend in the level of development of the phenomenon under study and in most cases are contained in the range from zero to unity. Large values of the measure sTMD indicate an expected high level of the development of the phenomenon.

The use of the spatial taxonomic measure of development in the analysis of the labour market in Poland

The article presents an analysis of the situation on the labour market in Poland in 2013¹³. The analysis conducted was used to demonstrate the suitability of the use of the spatial taxonomic measure of development in economic research. For the purpose of assessing the development of the labour market in Poland both the taxonomic measure of development and the spatial taxonomic measure of development were applied. The results obtained made it possible to show the differences between the measures and to justify the simultaneous use of the two measures in the analyses performed. These measures are in fact complementary through mutual complementarity while evaluating economic phenomena.

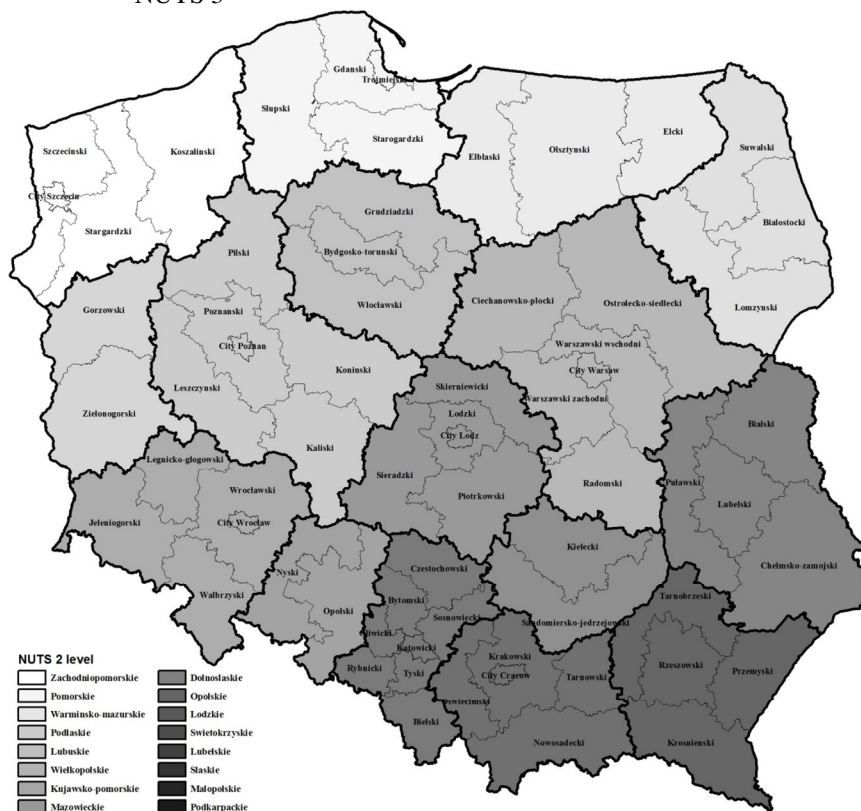
The study first used the territorial composition of Poland's 16 voivodships (NUTS 2 level) and then the territorial composition of 66 subregions (NUTS 3 level). The two territorial composition taken for the study are shown in Figure 2. The description of the situation on the labour market employed the variables used in Table 2. All of the selected variables are the determinants with a significant impact on the situation of the labour market. The variables X_1 , X_2 , X_3 , X_4 function as stimulants, and the

¹² In point 6 a different normalization method may be used and in point 7 a metric other than the Euclidean one.

¹³ The reason for choosing the year 2013 was the availability of all data.

variable X_5 is a destimulant¹⁴. The data on the selected variables were obtained from the Local Data Bank of the Main Statistical Office¹⁵.

Figure 2. The Polish administrative division - territorial composition of voivodships NUTS 2 and territorial composition of subregions NUTS 3



Source: Authors' compilation.

14 A destimulant was transformed into a stimulant based on formula (8).

15 The data was obtained from the website of the Main Statistical Office (GUS): www.stat.gov.pl.

Table 2. Variables selected for the purpose of the description the situation on the labour market

Variable	Description
X ₁	Average monthly gross wages and salaries
X ₂	Entities of the national economy in the REGON register per capita (working age population)
X ₃	Investment outlays per capita (working age population)
X ₄	Labour productivity (GDP/employed persons) ¹⁶
X ₅	Registered unemployment rate

Source: Authors' compilation.

In the first step of the study the taxonomic measure of development for the 16 voivodships was calculated using the TOPSIS method. The value of the measure TMD was obtained based on the variables taken from Table 2. The results are shown in Table 3, where column 2 presents the value of the composite index. The values of index allowed the working out of a ranking of regions in terms of the assessment of the situation on the labour market (column 3, Table 3). Then, based on the method of natural breaks¹⁷, grouping of voivodships was performed with the effect that each of the voivodships was assigned to one of the five classes. Relative to the situation on the labour market, these classes were subsequently named as follows: class 1 as 'very weak', class 2 as 'weak', class 3 as 'average', class 4 as 'good' and class 5 as 'very good' (column 4, Table 3).

Spatial analysis of regions belonging to the five classes indicates the possibility of dividing the Polish territory by the situation on the labour market into the western part of the country characterized by a well-developed labour market, and the eastern part of the weak situation on the labour market. In addition, the dominant role of the Mazowieckie voivodship (class 1) is visible in terms of the economic situation and the most developed labour market. Accordingly, the three areas with a similar labour market situation were separated arbitrarily (column 5, Table 3). Area 1 'the eastern part' was created from the voivodships assigned to classes 1 and 2, characterized by a weak or very weak situation on the labour market. These voivodships belong to the eastern part of the country. Area 2 'the western part' was formed from the voivodships contained in classes 3 and

¹⁶ GDP values were obtained for 2012 due to the lack of available data for the year 2013.

¹⁷ The idea of the method is to minimize the variance of the objects of the selected classes and to maximize the variance between classes (see: Jenks 1967).

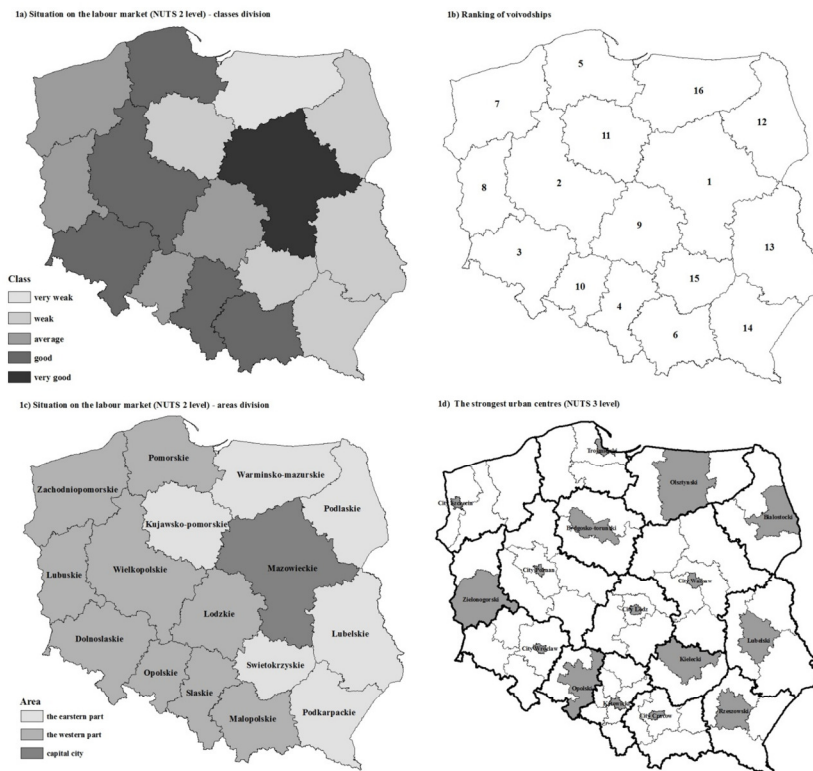
4, with a good and average labour market situation. Those voivodships form the western part of the country. The last one - area 3 'capital city' was created exclusively out of the Mazowieckie voivodship, which as the only one has a very good situation on the labour market.

Table 3. The situation on the labour market at the level of voivodships (NUTS 2 level)

Voivodship	TMD index	Ranking	Class	Area
Mazowieckie	0,935	1	5 (very good)	3 (capital city)
Dolnoslaskie	0,542	2	4 (good)	2 (the western part)
Slaskie	0,531	3	4 (good)	2 (the western part)
Wielkopolskie	0,500	4	4 (good)	2 (the western part)
Pomorskie	0,445	5	4 (good)	2 (the western part)
Malopolskie	0,372	6	3 (average)	2 (the western part)
Zachodniopomorskie	0,353	7	3 (average)	2 (the western part)
Lodzkie	0,311	8	3 (average)	2 (the western part)
Opolskie	0,264	9	3 (average)	2 (the western part)
Lubuskie	0,259	10	3 (average)	2 (the western part)
Lubelskie	0,185	11	2 (weak)	1 (the eastern part)
Podlaskie	0,169	12	2 (weak)	1 (the eastern part)
Kujawsko-pomorskie	0,154	13	2 (weak)	1 (the eastern part)
Swietokrzyskie	0,154	14	2 (weak)	1 (the eastern part)
Podkarpackie	0,140	15	2 (weak)	1 (the eastern part)
Warminsko-mazurskie	0,087	16	1 (very weak)	1 (the eastern part)

Source: Authors' compilation.

Figure 3. The situation on the Polish labour market at the level of voivodships (NUTS 2) and the strongest urban centres (NUTS 3)



Source: Authors' compilation.

The results were also shown in Figure 3. Figures 3a, 3b and 3c present Poland's territorial composition of 16 voivodships (NUTS 2), and Figure 3d additionally presented the territorial composition of 66 subregions (NUTS 3). The division of the voivodships into five classes made by means of the method of the natural breaks is shown in Figure 1a (column 4, Table 2). This division indicates the dominant role of the Mazowieckie voivodship (class 5), where the Polish capital city – Warsaw is situated. Then the following five voivodships with a good situation on the labour market (class 4) were distinguished: the Pomorskie voivodship, Wielkopolskie voivodship, Dolnoslaskie voivodship, Slaskie voivodship, and the Malopolskie voivodship. The average situation (class 3) on the labour market is typical of the Zachodniopomorskie voivodship, lubuskie voivodship, lodzkie voivodship and opolskie voivodship. Other

voivodships have a significantly weaker labour market situation compared to the voivodships of classes 1 and 2. The weak labour market conditions (class 2) can be seen in the Kujawsko-pomorskie voivodship, Swietokrzyskie voivodship, Podlaskie voivodship, Lubelskie voivodship and in the Podkarpackie voivodship.

The last of the voivodships - the Warminsko-mazurskie voivodship faces the worst labour market situation in Poland (class 1). In Figure 3b voivodships are numbered in accordance with the ranking based on the taxonomic measure of development (column 3, Table 2). The next figure (3c) presented the arbitrarily performed division of Poland into 3 areas (column 5, Table 3). There can be seen considerable differences between Poland's western part and eastern part relative to the level of development of the labour market.

In the case of the analysis made for the voivodships, one should pay attention to the fact that these regions are heterogeneous in terms of the situation on the labour market¹⁸. Moving to a lower level of aggregation (NUTS 3), it can be concluded that subregions belonging to one voivodship may have significant differences in the level of development of the labour market. In each of the voivodships we can distinguish subregions with the most developed urban centre or a group of cities. These centres vary widely in their level of economic development from other subregions of the voivodship. In addition, the strongest urban centres form separate subregions, while the less developed centres form a single subregion with the neighbouring administrative units. Figure 3d distinguishes for each of the voivodships subregions having the strongest urban centres. It turns out that areas 2 and 3 shown in Figure 3c have the strongest urban centres in Poland, which form separate subregions. They include the Polish capital city Warsaw (the Mazowieckie voivodship), the city of Poznan (the Wielkopolskie voivodship), the city of Wroclaw (the Dolnoslaskie voivodship), the city of Cracow (the Malopolskie voivodship), the city of Lodz (the Lodzkie voivodship), the city of Szczecin (the Zachodniopomorskie voivodship), the city of Katowice (the Katowicki subregion, the Slaskie voivodship), a group of the cities of Gdansk, Gdynia, Sopot (the Trojmiejski subregion, the Pomorskie voivodship). However, in

¹⁸ For instance, the Mazowieckie voivodship which has the best situation on the labour market is made up of subregions strongly differentiated in terms of the level of development of this market. In this voivodship there are subregions with a very good situation on the labor market (the city of Warsaw), with good (the Warszawski wschodni, the Warszawski zachodni, Ciechanowsko-plocki subregions), with average (Ostrolecko-siedlecki subregion) and with a weak situation (Radomski subregion).

the case of area 1, all major urban centres are much less developed and form subregions with their neighbouring regions. They include the cities of Bydgoszcz and Torun (the Bydgosko-torunski subregion, the Kujawsko-pomorskie voivodship), the city of Olsztyn (the Olsztynski subregion, the Warmińsko-mazurskie voivodship), the city of Białystok (the Białostocki subregion, the Podlaskie voivodship), the city of Lublin (the Lubelski subregion, the Lubelskie voivodship), the city of Kielce (the Kielecki subregion, the Świętokrzyskie voivodship) and the city of Rzeszów (the Rzeszowski subregion, the Podkarpackie voivodship). The impact of the strongest urban centres in the western part of the country causes that some neighbouring subregions of these centres are also characterized by a high level of economic development and a good situation on the labour market. A much weaker position of urban centres in the eastern part of Poland leads, in turn, to an even weaker labour market situation of most subregions in this part of the country.

The heterogeneity of the voivodships in terms of the situation on the labour market means that the analysis carried out at NUTS 2 level is insufficient. The study ought to use a lower level of aggregation. For this purpose, it is possible to adopt a territorial composition of subregions (NUTS 3). Subregions are administrative units where economic development and the situation on the labour market are relatively homogeneous¹⁹. Therefore, the values of the taxonomic measure of development were calculated for subregions with the use of the TOPSIS method. For this purpose, the variables contained in Table 2 were used again. The values of the measure allowed the preparation of the ranking of subregions. Then, on the basis of the values of the measure the subregions were divided into five classes using the method of natural breaks²⁰. The results are shown in Table 4. The second and the ninth columns contain the values of the TMR measure, the third and the tenth columns present the number of the ranking for each subregion, while the fourth and the eleventh columns show to which of the five classes a given subregion belongs.

¹⁹ This means that the analysis carried out for the subregions should allow drawing correct conclusions, and the analysis of the voivodships can only serve to formulate initial and very general conclusions.

²⁰ These classes are defined the same as in the case of the voivodships. Regarding the situation on the labor market, class 1 is described as 'very weak', class 2 as 'weak', class 3 as 'average', class 4 as 'good' and class 5 as 'very good'.

Table 4. The situation on the labour market in Poland at the level of subregions (NUTS 3)

Subregion	TMD index			sTMD index			Subregion	TMD index			sTMD index		
	M	R	K	M	R	K		M	R	K	M	R	K
City Warsaw	0,972	1	5	0,899	1	5	Olsztynski	0,166	34	3	0,189	43	2
City Poznan	0,490	2	5	0,509	2	5	Gdanski	0,166	35	3	0,211	35	3
Trojmiejski	0,477	3	5	0,450	4	5	Gorzowski	0,165	36	3	0,213	34	3
Legnicko-glogowski	0,427	4	5	0,414	6	5	Bytomski	0,164	37	3	0,246	27	3
Katowicki	0,419	5	5	0,476	3	5	Koszalinski	0,163	38	3	0,193	41	2
City Wroclaw	0,411	6	5	0,433	5	5	Bialostocki	0,162	39	3	0,155	56	2
City Cracow	0,406	7	5	0,407	8	5	Starogardzki	0,160	40	3	0,186	45	2
Warszawski zachodni	0,349	8	4	0,393	9	5	Oswiecimski	0,154	41	3	0,229	30	3
Tyski	0,349	9	4	0,409	7	5	Wloclawski	0,152	42	3	0,194	39	2
Rybnicki	0,315	10	4	0,391	1	5	Koninski	0,151	43	3	0,198	38	2
Gliwicki	0,310	11	4	0,392	1	5	Czestochowski	0,149	44	2	0,204	36	2
Poznanski	0,292	12	4	0,331	1	4	Lodzki	0,148	45	2	0,183	46	2
City Szczecin	0,289	13	4	0,305	1	4	Radomski	0,147	46	2	0,192	42	2
Piotrkowski	0,285	14	4	0,305	1	4	Tarnobrzeski	0,143	47	2	0,155	57	2
Ciechanowsko-plocki	0,280	15	4	0,284	2	4	Sandomiersko-jedrzejewski	0,142	48	2	0,187	44	2
City Lodz	0,277	16	4	0,284	2	4	Stargardzki	0,138	49	2	0,204	37	2
Sosnowiecki	0,259	17	4	0,298	1	4	Nowosadecki	0,131	50	2	0,167	54	2
Bydgosko-torunski	0,254	18	4	0,258	2	3	Grudziadzki	0,127	51	2	0,177	50	2
Bielski	0,243	19	4	0,341	1	4	Slupski	0,127	52	2	0,170	53	2
Lubelski	0,242	20	4	0,237	2	3	Pilski	0,126	53	2	0,177	49	2
Warszawski wschodni	0,241	21	4	0,299	1	4	Elblaski	0,124	54	2	0,176	51	2
Wroclawski	0,240	22	4	0,301	1	4	Nyski	0,120	55	2	0,175	52	2

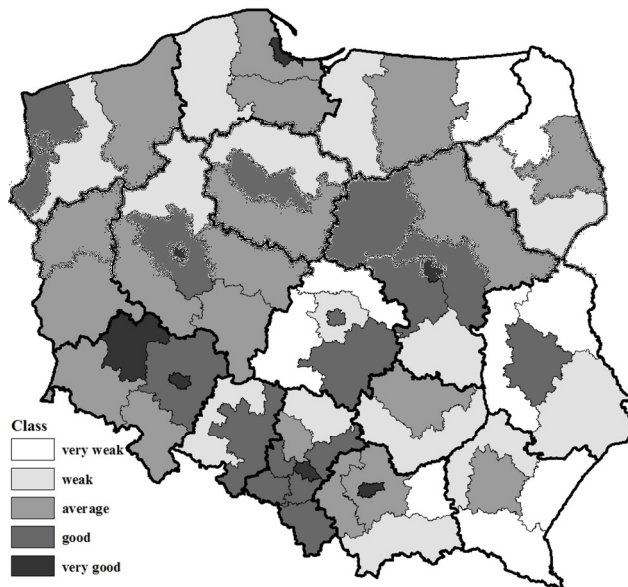
Szczecinski	0,232	23	4	0,271	2 2	4	Chelmsko- zamojski	0,118	56	2	0,140	60	1
Opolski	0,226	24	4	0,286	1 9	4	Lomzynski	0,115	57	2	0,129	61	1
Leszczynski	0,182	25	3	0,259	2 3	3	Skierniewicki	0,110	58	1	0,182	47	2
Walbrzyski	0,182	26	3	0,227	3 1	3	Pulawski	0,110	59	1	0,148	58	1
Rzeszowski	0,181	27	3	0,179	4 8	2	Tarnowski	0,109	60	1	0,141	59	1
Kielecki	0,178	28	3	0,213	3 3	3	Sieradzki	0,095	61	1	0,166	55	2
Kaliski	0,176	29	3	0,239	2 8	3	Elcki	0,095	62	1	0,105	64	1
Zielonogorski	0,175	30	3	0,250	2 6	3	Suwalski	0,094	63	1	0,108	63	1
Jeleniogorski	0,174	31	3	0,251	2 5	3	Krosnienski	0,088	64	1	0,111	62	1
Ostrolecko- siedlecki	0,167	32	3	0,193	4 0	2	Bialski	0,067	65	1	0,097	65	1
Krakowski	0,167	33	3	0,223	3 2	3	Przemyski	0,064	66	1	0,083	66	1

M - value of the TMD or sTMD measure, R - position in the ranking, K - the class to which each of the regions was assigned. Source: Authors' compilation.

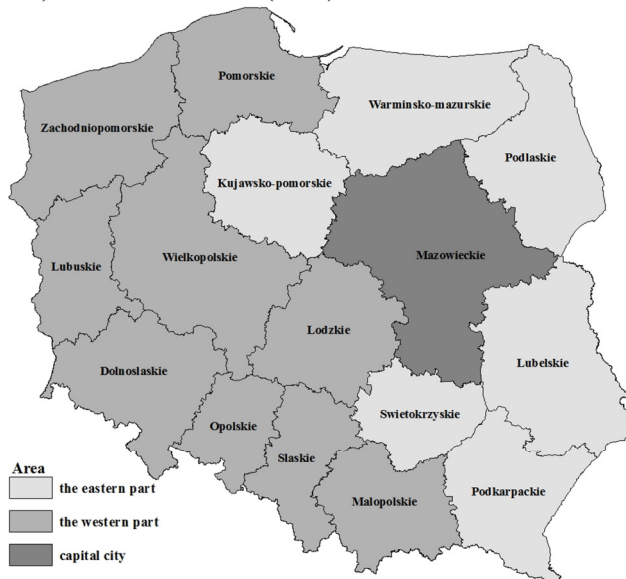
Figure 4 shows the spatial variability of situation in the labour market as measured by means of TMD. The results presented in Table 3 and Figure 4a allow the assessment of the situation on the labour market in Poland. The assessment carried out in the article was reduced only to the selection of subregions with the best situation for each voivodship. The voivodships were considered in the order of belonging to the three areas shown in Figure 3c.

Figure 4. The situation on the labour market in Poland at the level of subregions (NUTS 3)

4b) Situation on the labour market (NUTS 3) - class division



4b) Situation on the labour market (NUTS 2) - areas division



Source: Authors' compilation.

Area 2 referred to as ‘the western part’ is composed of nine voivodships. In the Zachodniopomorskie voivodship the situation on the labour market of the city of Szczecin and the Szczecinski subregion is good. Within the Pomorskie voivodship, the Trojmiejski subregion can boast of a very good situation on the labour market. Both subregions of the Lubuskie voivodship, the Gorzowski and Zielonogorski subregions, have the average situation on the labour market. In the Wielkopolskie voivodship a key centre generating a growth area is the city of Poznan, with a very good situation on the labour market. In addition, the Poznanski subregion surrounding the city of Poznan has a good situation on its labour market. It should be emphasized, however, that the area of growth in this region is moving towards the Dolnoslaskie voivodship. Within the Dolnoslaskie voivodship, the city of Wroclaw and the Legnicko-glogowski subregion can boast of a very good situation on their labour markets. Moreover, a good situation on the labour market occurs in the Wroclawski subregion. Within the Lodz voivodship, a good situation on the labour market can be seen in the city of Lodz and the Piotrkowski subregion. Within the Opolskie voivodship, the only subregion with a good situation in the labour market is the Opolski subregion. The Slaskie voivodship is characterized by the best-developed labour market compared to other voivodships. In the case of the Katowicki subregion, the situation on the labour market is very good. The following five subregions: the Rybnicki, Gliwicki, Sosnowiecki, Tyski, and Bielski subregions have a good situation on the labour market. In the Malopolskie voivodship, which is adjacent to the Slaskie voivodship, a very good situation on the labour market can be seen in the city of Cracow, which constitutes the main urban centre of the voivodship.

Area 1 – ‘the eastern part’ consists of six voivodships. All voivodships in Area 1 have a low economic potential. The impact of the most developed cities is local, which translates into a weak situation on the labour market of the other subregions. Within the Kujawsko-pomorskie voivodship only the Bydgosko-torunski subregion has a good situation on the labour market. Further five voivodships - the Swietokrzyskie, Warminsko-mazurskie, Podlaskie, Lubelskie and Podkarpackie voivodships are characterized by a significantly weaker labour market situation, if compared with the other eleven provinces. In this case, a good or average situation in the labour market is limited to the Kielecki, Olsztynski, Bialostocki, Lubelski and Rzeszowski subregions, where the capital cities of these voivodships are situated. The remaining subregions of the five voivodships have a weak or very weak situation on the labour market.

In the case of Area 3 – ‘the capital city’ consisting solely of the Mazowieckie voivodship, the city of Warsaw has a very good situation on its labour market. Warsaw with the status of the Polish capital city can

boast of the highest value of the TMD measure, therefore, it ranks first in the subregions ranking. The impact of the city of Warsaw reaches out far beyond the boundaries of the city. In consequence, the growth area of Warsaw has been extended to the Warszawski wschodni subregion, the Warszawski zachodni subregion and the Ciechanowsko-plocki subregions. These subregions have a good situation on the labour market.

The next step was to calculate the spatial taxonomic measure of development in accordance with the procedure proposed in the article. For this purpose, first, Moran I statistic for each of the variables taken from Table 1 was calculated, where a standardized spatial contiguity matrix W was assumed. The received test statistics are shown in Table 4 and p-values are given in parentheses. The results indicated statistically significant spatial dependence for all variables. Therefore, estimation of the parameters of the spatial autoregressive model SAR was made following the formula (6) (see Table 5).

Table 5. Results of Moran test and of the estimation of the parameters of the SAR model

Variable	Moran I statistic	Estimate of the parameter ρ
X ₁	0,156 (0,019)	0,355 (0,009)
X ₂	0,086 (0,042)	0,236 (0,048)
X ₃	0,122 (0,039)	0,294 (0,023)
X ₄	0,458 (~0,00)	0,713 (~0,00)
X ₅	0,253 (~0,00)	0,606 (~0,00)

Source: Authors' compilation.

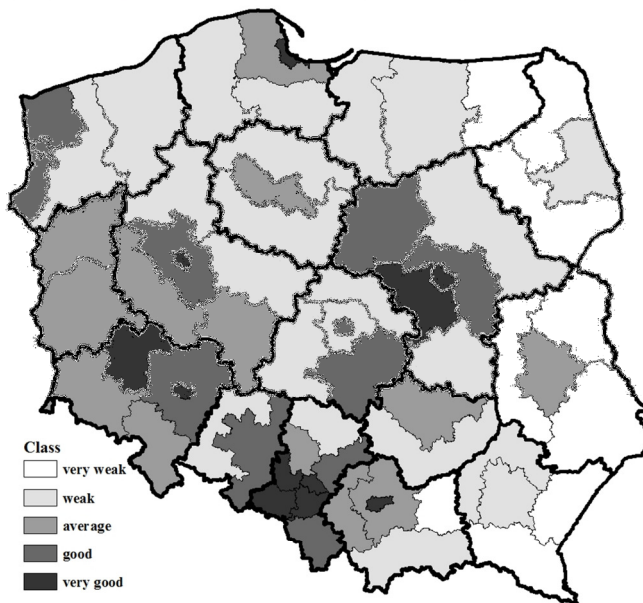
The obtained estimates of parameter ρ allowed the transformation of the variables using the formula (7). During the transformation of the variables the same spatial weight matrix was applied as in the case of the Moran test. In the last step, using the transformed variables, the values of the spatial taxonomic measure of development sTMD were calculated in accordance with the formula (10). The results allowed us to re-rank the subregions and to divide them again into 5 classes using the methods of natural breaks. In this way subregions were ascribed to the following classes with different levels of the expected situation on the labour market : class 1 - 'very weak', class 2 - 'weak', class 3 - 'average', class 4 - 'good' and class 5 - 'very good'. 'The expected situation' is understood as a trend in the level of development of the labour market, resulting from the current

situation and existing spatial mechanisms. The sTMD values, as in the case of TMD, are shown in Table 3. The fifth and the twelfth columns show the value of the measure, the sixth and the thirteenth columns contain the ranking number for each of the subregions, and the seventh and the fourteenth columns show the belonging of the subregions to the classes.

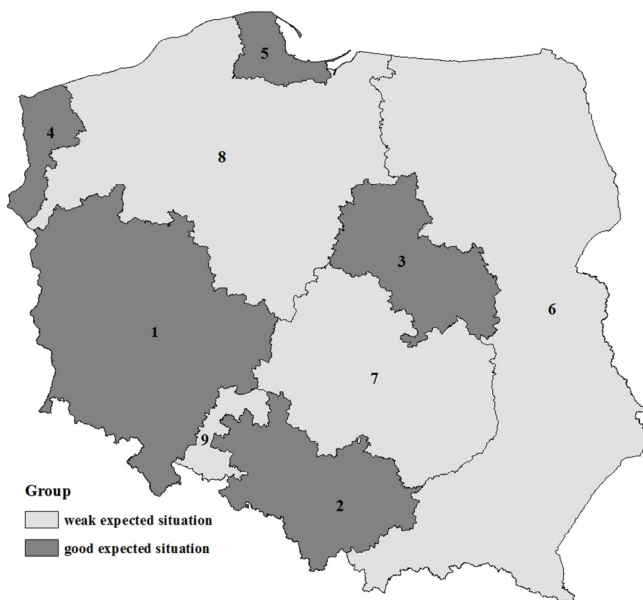
The values of the spatial taxonomic measure of development, in turn, helped to establish the expected situation on the labour market in Poland. Figure 5a shows the spatial variability of the sTMD values (see Table 4). In accordance with the adopted division of subregions into classes, the following were included to the class with a very good expected situation on the labour market: the city of Warsaw, the city of Poznan, the city of Wroclaw, the city of Cracow and also the following subregions: the Trojmiejski, Legnicko-glogowski, Katowicki, Tyski, Gliwicki and Rybnicki. Together with the Polish capital city of Warsaw they constitute the most economically developed subregions. The good expected situation on the labour market contained the city of Lodz, the city of Szczecin and subregions: the Szczecinski, Warszawski wschodni, Ciechanowsko-plocki, Piotrkowski, Poznanski, Wroclawski, Opolski and Sosnowiecki. The average expected situation on the labour market included the following subregions: Gdanski, Gorzowski, Zielonogorski, Bydgosko-torunski, Leszczynski, Kaliski, Jeleniogorski, Walbrzyski, Kielecki, Lubelski, Bytomski, Oswiecimski, and city of Cracow. The remaining subregions form spatial clusters of a weak or very weak expected situation on the labour market. The results indicate the dominant role of the Mazowieckie, Slaskie, Wielkopolskie, and Dolnoalaskie voivodships.

Figure 5. The expected situation on the labour market in Poland at the level of subregions (NUTS 3)

5a) Expected situation on the labour market (NUTS 3) - class division



5b) Spatial clusters of regions



Source: Authors' compilation.

The variability of the spatial taxonomic measure of development presented in Figure 5a allows the identification of spatial clusters of subregions with the similar expected situation on the labour market. Accordingly, the spatial clusters were divided into the following two groups: group 1 'good expected situation' and group 2 'weak expected situation' (see Figure 5b). Group 1 was assigned five clusters of the good expected situation on the labour market, and group 2 three clusters, where the expected situation is reverse. Among the first group of clusters, the largest spatial cluster proved to be the cluster composed of the following subregions belonging to the Lubuskie, Wielkopolskie and Dolnoslaskie voivodships (cluster no. 1). The major growth centres in the cluster are the cities of Poznan and of Wroclaw. The next largest cluster is composed of the Opolskie subregion and subregions of Slaskie, Malopolskie voivodships (cluster no. 2). The major growth centres here are the biggest cities in the Slaskie voivodship (Katowice, Sosnowiec, Gliwice, Tychy) and the cities of Cracow and of Opole. The third cluster is formed of the subregions of the Mazowieckie voivodship (cluster no. 3). This cluster is focused around Warsaw and is the most dynamically developing area because of Warsaw's status of the capital city. Additionally, two areas in the Zachodniopomorskie and Pomorskie voivodships were depicted where the good expected situation on the labour market is limited to the city of Szczecin and the Szczecinski subregion (cluster no. 4), to the Trojmiasto subregion (the cities of Gdansk, Gdynia, Sopot), and to the Gdanski subregion (cluster no. 5). In the case of these two areas, the good expected situation on the labour market results from the fact that the cities of Szczecin, Gdansk, Gdynia are port cities with access to the Baltic Sea.

Figure 5b highlights significantly larger spatial clusters with the weak expected situation on the labour market. The largest spatial cluster of group 2 is formed by the subregions situated in eastern Poland (cluster no. 6). The cluster comprises the subregions of the Warminko-mazurskie, Mazowieckie, Podlaskie, Lubelskie, Podkarpackie and Malopolskie voivodships. In this cluster there are four major urban centres, the cities of Olsztyn, Bialystok, Lublin and of Rzeszow. Another cluster no. 7 is composed of the subregions belonging to the Mazowieckie, Lodzkie, Swietokrzyskie and Slaskie voivodships. In this cluster there are four major urban centres Kielce, Radom, Lodz, Czestochowa. The last cluster no. 8 consists of the subregions situated within the Zachodniopomorskie, Wielkopolskie, Pomorskie and Kujawsko-pomorskie voivodships. The major urban centres of the cluster are the cities of Bydgoszcz, Torun, Pila, Koszalin, and of Slupsk.

Despite the fact that in the selected clusters of group 2 are situated large urban centres, they do not have sufficient potential to create strong

growth areas and their impact is purely local. In addition, these centres are developing more slowly than the urban centres of the clusters belonging to group 1. In the future, it may contribute to the perpetuation of the situation in the clusters of group 2 and to the extension of their territory by another subregions.

The difficult situation of the Nysa subregion (no. 10) needs to be emphasised. The situation of this subregion is unique because it is situated between two clusters having the good expected situation on the labour market (clusters no. 1, no. 2). In the case of the Nysa subregion, the close proximity of the city of Wroclaw has a negative impact on the development of that subregion, where the most valuable resources are being relocated to the city of Wroclaw and to the Wroclaw subregion.

The taxonomic measure of development and the spatial taxonomic measure of development are mutually complementary measures in terms of information. The measure TMD allows the assessment of the current situation of the studied phenomenon and the measure sTMD allows determining the expected level of its development. The measure sTMD has a tendency to form spatial clusters of regions with a high or low expected level of development of the examined phenomenon. This is due to the fact that in order to determine the composite index, the initial values of the variables X_k for the selected region get converted. The values of selected variable X_k for neighbouring regions are added to the value of this variable of the region i (formula 7). This change causes the convergence of the value of the variable X_k for neighbouring regions. If a majority of assumed variables is characterized by significant spatial dependence, there will be a tendency to converge the spatial taxonomic measure of development value to the neighbouring regions.

In the case of the occurrence of spatial dependence for most variables, rankings of regions made on the basis of the measures TMD and sTMD may differ from each other. Any region can take a lower position in the ranking based on the measure TMD compared with the ranking based on the measure sTMD, if there is a strong spatial impact of their neighbours characterized by high values of the measure TMD. An opposite situation may occur in the case of the neighbourhood of regions with low values of the measure TMD. Since the assessment of the expected situation on the labour market may increase or decrease due to the spatial impact of neighbouring subregions, then subregions will naturally tend to cluster spatially into groups with similar values of the measure sTMD.

The differences in the rankings based on the measures TMD and sTMD will be discussed using the example of the Mazowieckie voivodship and the Lubelskie voivodship (see Table 3). The area of the Mazowieckie

voivodship comprises six subregions - the city of Warsaw, the Warszawski wschodni subregion, the Warszawski zachodni subregion, the Ciechanowsko-plocki subregion, the Radomski subregion, and the Ostrolecko-siedlecki subregion. When calculating the value of the measure sTMD for any subregion, the weighted values of the variables X_k from the remaining 65 subregions were added to the initial values of the same variables. Since the city of Warsaw has the highest values of the variables X_k , then the transformed values of the variables Z_k increase to a greater extent for the subregions neighbouring with Warsaw than for Warsaw itself. Therefore, as a result of the transformation of the variables, the value of the measure sTMD for Warsaw and its neighbouring subregions (the Warszawski wschodni and the Warszawski zachodni subregions) converged and the positions held in the ranking could be improved. In the case of the other subregions of the Mazowieckie voivodship, the situation is as follows: the Ciechanowsko-plocki and the Radomski subregions have achieved positions closer to Warsaw - the Ciechanowsko-plocki subregion due to the proximity of the Warszawski zachodni subregion and the Bydgosko-torunski subregion (those are subregions with a good situation on the labour market), and the Radomski subregion due to the proximity of the Warszawski zachodni subregion, Kielecki and Piotrkowski subregions (they have a good situation the labour market). The Ostrolecko-siedlecki subregion, however, departed from Warsaw, due to the proximity of subregions with a much weaker labour market situation – the Lomzynski, Pulawski, and Elcki subregions. Finally, the Warszawski wschodni subregion, the Warszawski zachodni subregion, the Ciechanowsko-plocki subregion and the Radomski subregion neared Warsaw's value of the measure sTMD, and the Ostrolecko-siedlecki subregion departed from the value. This resulted in the identification of a spatial cluster around Warsaw classified as group 1 and the assignment of the Ostrolecko-siedlecki subregion to a group 2 cluster. The differences in the values of the TMD and sTMD affect the results of the ranking. In the ranking based on the measure sTMD Warsaw remained on the first position. The Warszawski zachodni subregion and the Ciechanowsko-plocki subregion also remained unchanged in the ranking. The Warszawski wschodni subregion and the Radomski subregion moved up in the ranking (the Warszawski wschodni one moved up from the 24th position to the 19th, and Radomski from the 51st to 44th position). The Ostrolecko-siedlecki dropped in the ranking from the 46th position to 51st, due to the proximity of the subregions with a very weak situation on the labour market in the northern and eastern parts of Poland.

The situation looks quite different in the case of the Lubelskie voivodship. The voivodship consists of the following four subregions: the

Lubelski, Pulawski, Bielski and Chelmsko-zamojski subregions. In the voivodship only the Lubelski subregion, which includes the city of Lublin, has the potential for growth and has a good situation on the labour market. However, this potential is so weak that the Lubelski subregion does not significantly affect the neighbouring subregions with a much weaker labour market situation. The result is that the values of selected variables (Table 2), and the measure of TMD for the Lubelski subregion far outweigh the values of the variables for the neighbouring subregions: the Pulawski, Bialski and Chelmsko-zamojski subregions. The neighbourhood of the Lubelski subregion with the subregions with a very poor labour market situation resulted in a fall in the position of this subregion in the ranking based on sTMD, if compared with the ranking based on the TMD. The negative impact of the subregions adjacent to the Lubelski subregion resulted in a fall of this subregion from the 22nd to 31st position. The ranking positions of the Bielski subregion and the Chelmsko-zamojski subregion did not change. However, the ranking position of the Pulawski subregion rose from 59th to 57th. This is due to the spatial location of the subregion, which is adjacent to the Lubelski subregion, the Warszawski wschodni subregion and the Ostrolecko-siedlecki subregion with a significantly better situation on the labour market.

Conclusions

The realisation of the objective set in the present article allowed the development of the procedure for constructing the spatial taxonomic measure of development sTMD using the TOPSIS method. The need for the construction of the measure results from the problem of the presence of spatial dependence observed for most economic phenomena. Spatial dependence was taken into account while constructing the measure by using the matrix of potential impact $V(W)$. Therefore, the spatial taxonomic measure of development allows determining trend in the level of development of the analysed phenomena, assuming the impact of the existing spatial mechanisms.

The proposed construction of the sTMD measure has already been applied for the purpose of analysis of the situation on the labour market in Poland. The study allowed us to assess the situation in 2013 and to identify the trend in the development of the labour market. As a result of the study, two groups of spatial clusters were also identified. Clusters of group 1 consisted largely of subregions with the good expected situation on the labour market. Clusters of group 2 were dominated by subregions with the

weak expected situation on the labour market. That means that with the existing spatial mechanisms the labour market tends to regional divergence. A high level of development of the labour market is predicted only for the areas around Poland's most developed urban centres. However, in the case of other areas the situation on the labour market is expected to worsen. This is due to the drain of valuable resources from subregions belonging to group 2 clusters, which naturally flow into clusters from group 1. The results received point to the fact that without intense, deliberate state policy, the current differences in the level of the labour market will continue to increase and the differences in the level of economic development will deepen.

The analysis appointed to the usefulness of the proposed measure sTMD, which is complementary to the use of the taxonomic measure of development in the process of explaining the economic reality. The use of the spatial taxonomic measure of development allows expanding the results obtained on the basis of TMD by conclusions concerning the trend in development of the analysed phenomenon. This means that by taking into account spatial dependence the use of the measure sTMD in economic research gives us a fuller explanation of the variability of phenomena.

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