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THE SPATIAL STRUCTURES OF EUROPE
PROSTORSKE STRUKTURE V EVROPI

Áron Kincses, Zoltán Nagy, Géza Tóth

Europe is characterized by high regional variety.
Evropo zaznamuje pestrost regij.

The spatial structures of Europe

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ABSTRACT: Our study aims at describing the spatial structure of Europe with spatial moving average, potential model and the bidimensional regression analysis based on gravity model. Many theoretical and practical works aim at describing the spatial structure of Europe. Partly zones, axes and formations, partly polycentric models appear in the literature. We illustrate their variegation by listing, without any claim to completeness (since that could be the subject of another study), a part of them. Based on our examinations, the engraving of the structures that we described can be seen. The position of the core area of EU countries clearly justifies the banana shape and in relation to it, the catching up regions take shape in several areas.

KEY WORDS: geography, spatial models, moving average, potential model, gravity model, bidimensional regression, GDP, Europe

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1 Introduction

There have been many attempts to reveal and visualise the varied economic and social structural image of Europe in the last decades. These models attempt to demonstrate the determinant elements of the geographic space, the complex systems among them and the characteristics of this space structure. Spatial structural visualizations are differentiated along two approaches: one including zones, axes and formations and the other one including polycentric models.

The first provocative form was published in the study of Brunet (1989) as the »European Backbone«. Later it was called by its popular name »Blue Banana«. The authors drew a banana-shaped form to visualise the economic core area approximately from Liverpool to Nice or from London to Milan (Figure 1). Our figures present – without any claim to completeness – the approaches that we consider to be the most important ones.

A form similar to the banana can also be found in East-Central Europe called the »Central European Boomerang« (see Figure 1). According to Gorzelak (1996), the determinant areas of this form – stretching from Gdansk to Budapest and including Poznan, Wroclaw, Prague and the triangle of Vienna-Bratislava-Budapest – are the capitals, the real places of development.

Further form that has appeared in the literature is the »Red Octopus«, the body and the Western arms of which stretch between Birmingham and Barcelona toward Rome and Paris. It stretches toward Copenhagen-Stockholm (Helsinki) to the North and toward Berlin-Poznan-Warsaw and Prague-Vienna-Budapest to the East (van der Meer 1998) (Figure 2). Unlike earlier visualizations, this form includes the group of developed zones and their core cities, highlighting the possibilities to decrease spatial differences in this way as well by visualizing polycentricity and eurocorridors (Szabó 2009). The »Blue Star« is a bit similar to this form. In spite of the fact that it has not become as popular, the »Blue Star« also indicates the directions of development and the dynamic areas with the visualization of arrows and therefore makes future references possible (Dommergues 1992) (Figure 3).

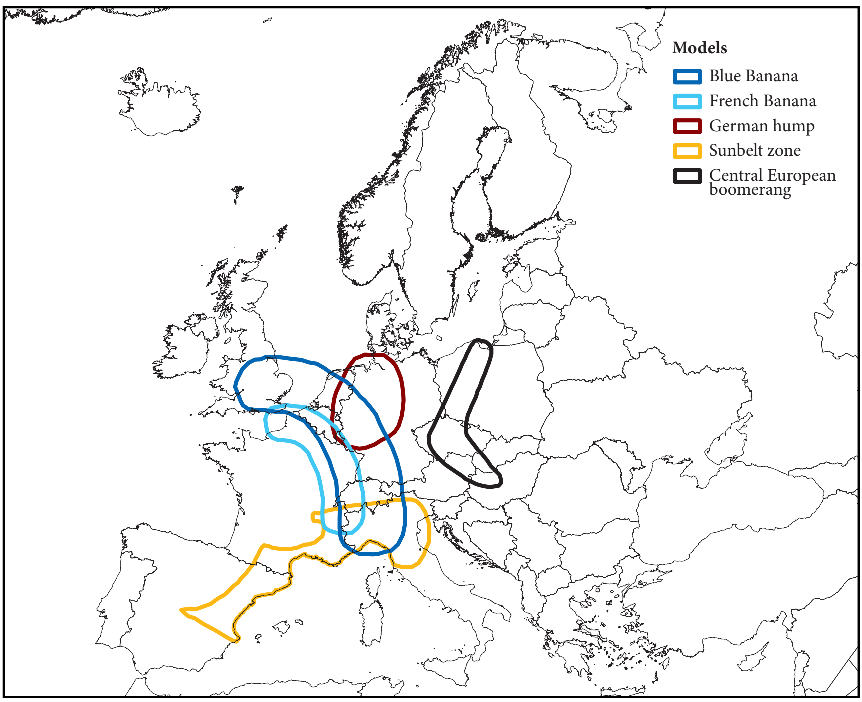

Figure 1: Spatial structure models I (source: own compilation based on Brunet 1989; Gorzelak 1996; Kunzmann 1992; Schatzl 1993; Hospers 2002).

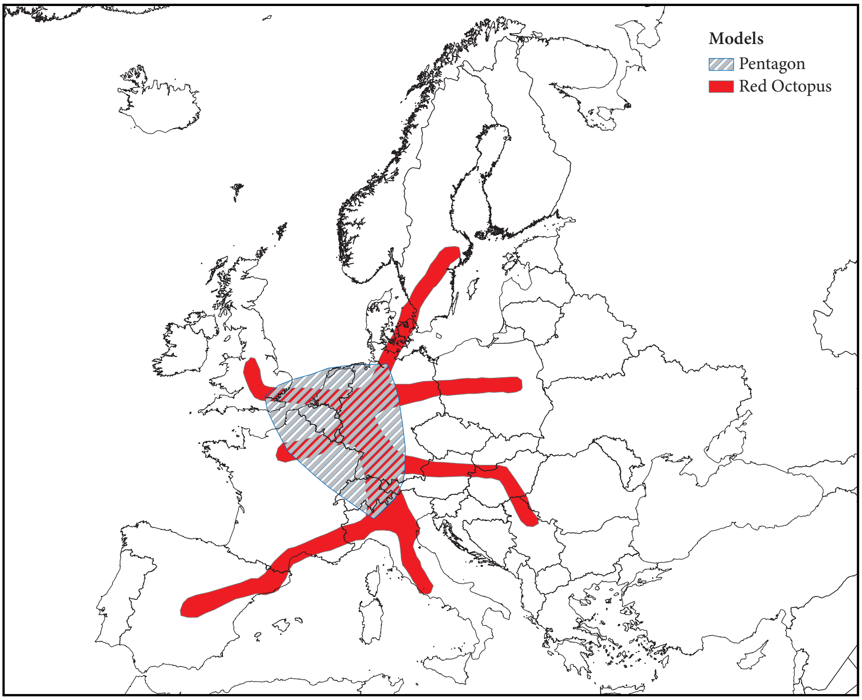

Figure 2: Spatial structure models II (source: own compilation based on van der Meer 1998 and ESDP 1999).

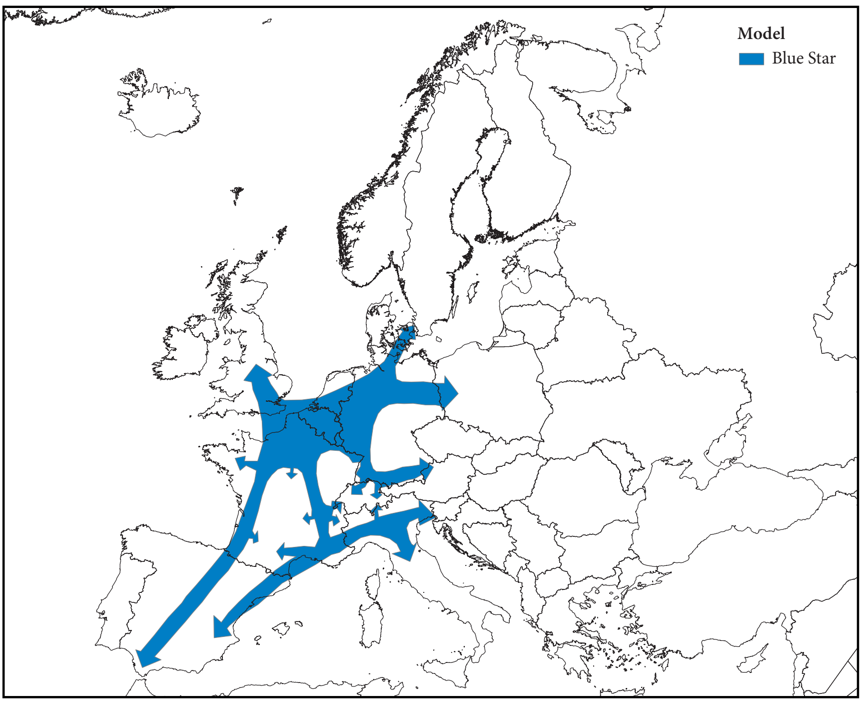

Figure 3: Spatial structure models III (source: own compilation based on Dommergues 1992).

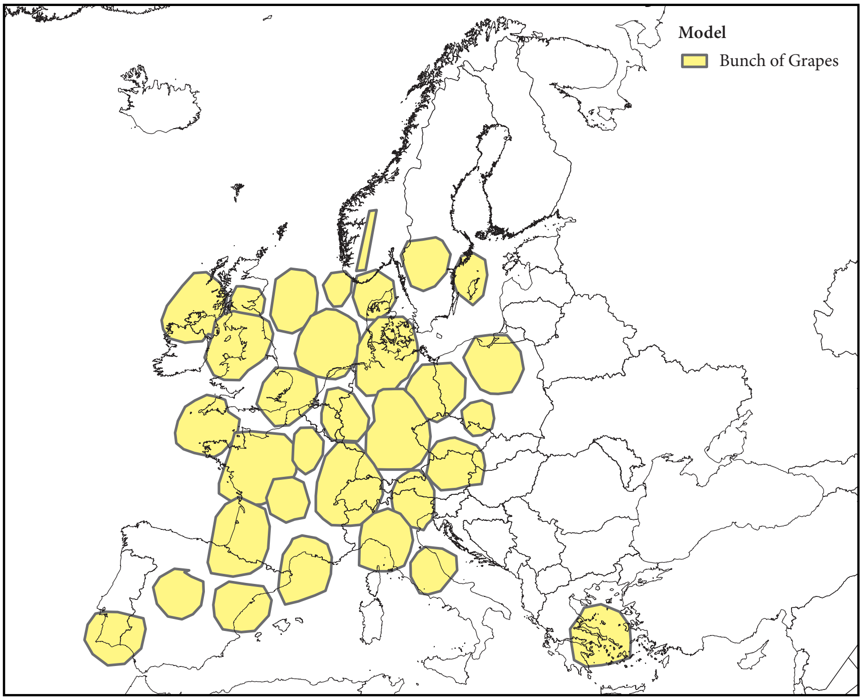

Figure 4: Spatial structure models IV (source: own compilation based on Kunzmann 1992).

The »European Pentagon« (Figure 2) is the region defined by London–Paris–Milan–Munich–Hamburg in the European Spatial Development Perspective (ESDP) in 1999.

The other important group in the visualization of spatial structure highlights urban development, the dynamic change of urban areas and the polycentric spatial structure (one of them can be seen on Figure 4). Kunzmann and Wegener (Kunzmann and Wegener 1991; Kunzmann 1992, 1996; Wegener and Kunzmann 1996) did not agree with the spatial description of the »Blue Banana« and other forms. They believe that the polycentric structure of our continent is determined by the metropolitan regions (which are situated not only within the »Blue Banana«), situated in a »Bunch of Grapes« shape. After this, polycentricity became an increasingly popular idea and one of the key elements of ESDP 1999. One of the reasons for the strengthening of polycentric characteristics is that since the 1990s, Europe has been characterised by a spatial concentration process.

This structure is reflected in the so-called MEGA zones (Nordregio 2004) as well, that highlight the complexity of the European spatial structure and also the visualization of the core areas; they also highlight the increase in the differences between urban and rural areas and the differences between big cities and rural areas.

In the next sections we examine the background of the spatial structural relations and models described above more thoroughly with the use of three methods and with the help of spatial models, each representing a different approach to the problem. In all of our examples, we apply GDP values as a determining measure of territorial development, as we believe that its use allows a detailed analysis of spatial structure.

2 Spatial moving average

The method of the spatial moving average can be used in the analysis of spatial phenomena and basic structure (Dusek 2001). In our analysis, our aim was to reveal stronger relationships with the help of moving averages. This can be done by finding the appropriate aggregation.

In the case of a given elemental unit, the spatial moving average of the examined characteristic can be found by calculating the average of the values for the surrounding areas, defined based on the given topological characteristics in Equation (1) (Haining 1978):

$$M(x_i) = \frac{\Sigma(f_j \cdot x_j)}{\Sigma f_j} \qquad (1)$$

for elements where $d(x_i; x_j) \leq m$ where $M(x_i)$ is the moving average of point i, $d(x_i, x_j)$ is the distance between the centres of i and j regions and m is the extension of the moving average (radius). x_j refers to the value to be averaged belonging to the j^{th} observation, i.e., per capita GDP, and f_j is the frequency or weight belonging to the j^{th} observation. In this case, if the moving average of per capita GDP is calculated, it is the population.

In this case, the level of aggregation is defined in a way to ensure its link to a territorial level that has currently been analysed. This was the NUTS1 level in our analysis. This territorial level was measured at its average extension, since supposing that the average area of the NUTS1 regions is a circle, a circle with 70 km radius is given. We carried out the calculations applying a 70 km radius, but we still judged our result to provide too fragmented picture. We presumed that the reason for this can be the relatively large dispersion among the areas of the NUTS1 level regions. Therefore we considered it more appropriate to define the radius of the moving average as 100 km; then, by increasing it by 20 km, we carried out the calculations up to a radius of 200 km. The reason for increasing the radius is that the higher the degree of aggregation, the higher the abstraction is, although after a certain size the loss of information increases as well.

The resulting map is much less fragmented compared to the base data, thus providing a possibility to carry out a more detailed analysis. Based on the map (Figure 5), we can conclude that the regions in the most favourable position in Europe – the engines of the economy – emerge from the examined areas like islands. These regions are primarily certain southern provinces in Germany, the regions of Rome and Northern Italy; the Northern part of Switzerland, a considerable part of Austria, the agglomerations of

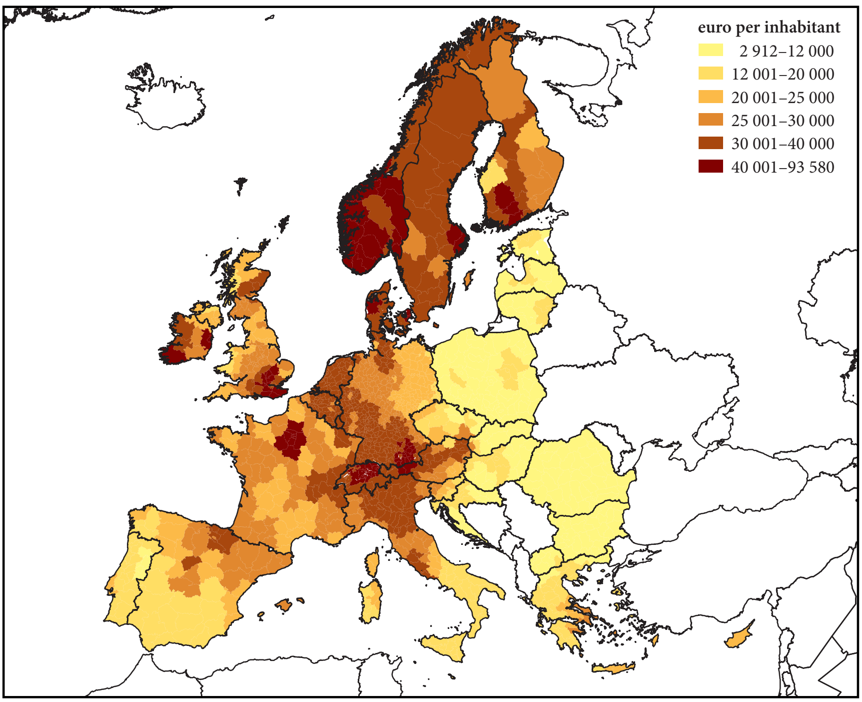

Figure 5: Spatial moving average of per capita GDP (2008) calculated with 100 km radius.

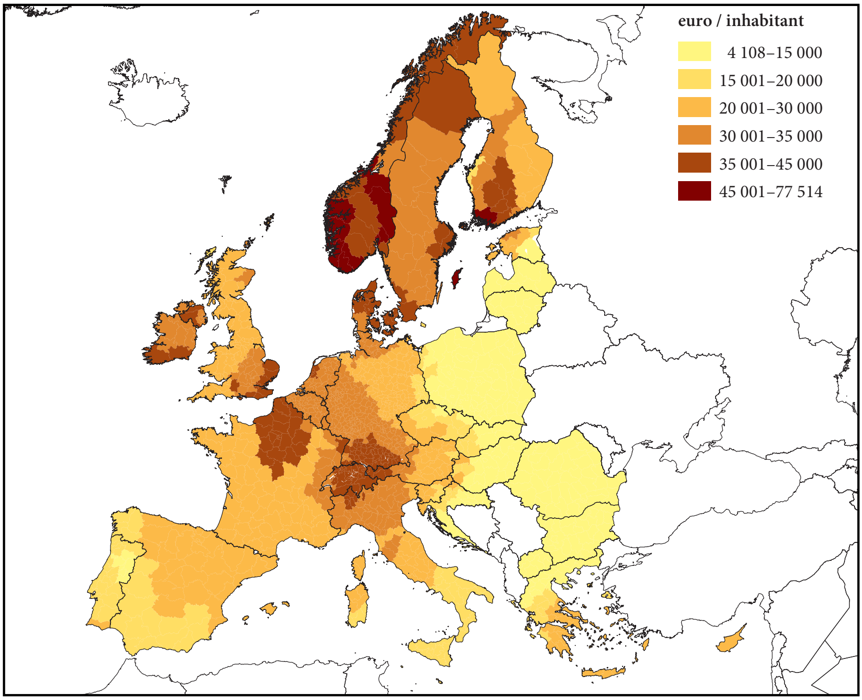

Figure 6: Spatial moving average of per capita GDP (2008) calculated with 200 km radius.

London and Paris, most of the area of the Benelux countries and of Denmark, the core area including a considerable number of the regions of each Scandinavian country. Besides these, outstanding values can only be found in the case of some regions. Such outstanding islands can be South Ireland (O'Reilly 2004), North Spain (Basque Country) and South Scotland. Considering Eastern European regions, the effect of the Iron curtain is still determinant. In this part, these are mainly the agglomerations of the capitals (especially Bratislava) that emerge from their surrounding; the degree to which they lag behind the above mentioned regions is, however, considerable. Out of the regions of the countries belonging to the formerly socialist block, only a few have the potential to link to the mentioned core areas. In this context, only some regions of Slovenia (especially Ljubljana (see Ravbar, Bole and Nared 2005) and the Czech Republic can be highlighted as positive examples.

With the above-described increase of the radius, we intended to increase the degree of abstraction. We increased the radius by 20 km each time, which made the results smoother. The outstanding areas are isolated from their surroundings; therefore, the main centres kept crystallizing. The results of the 200 km moving average can be seen on Figure 6.

3 About gravity and potential models

3.1 Relationship between space and weight, separating potential

One of the methods most frequently applied to examine spatial structure in the literature is the potential model. The general formula for potential models is given in Equation (2) (see for example in Hansen 1959):

$$A_i = \sum_j D_j \cdot F(c_{ij}) \qquad (2)$$

where A_i is the potential of a region i (NUTS3 regions), D_j is the mass of the region j, c_{ij} is the distance between the centre of i and j regions (straight line distances) and $F(cij)$ is the resistance factor.

The potential therefore is calculated from the sum of its own and internal potentials (Pooler 1987) using Equation (3):

$$\sum A_i = SA_i + BA_i \tag{3}$$

where ΣA_i is the overall potential of the area i, SA_i is its own and BA_i is the internal potential. The potential value in a given point is therefore determined by the internal and own potential (the sum of its own mass and the effect of its own area size). The own potential refer to the effect of the region i on its own potential, while internal potential shows the impact of all other regions on the potential of region i.

Based on the topology of the geometry of potential models, one can conclude that whichever model is used, a common point is that they measure the effects of the position of a space range and the size distribution of the masses as described in Equation (4). The position of the space range is basically defined by the geographical position. This means that for a given potential value, it is not possible to decide whether it is a consequence of the position of the favourable/unfavourable (settlement, regional) structure, position or masses, of the area size or of the effect of its own mass. Therefore, we aim at separating these effects, describing the share of the parts in the overall potential values and introducing territorial differences.

$$\sum A_i = BA_i + SA_i = U_i^{mass\,distribution} + U_i^{location} + U_i^{mass\,weight} + U_i^{area\,size} \tag{4}$$

In an arbitrary point of the space, the effect of the potential derived from the spatial location refers to the value that could have been provided that the masses are the same in each of the specified territorial units, as in Equation (5):

$$U_i^{location} = \sum_j \frac{\left(\frac{\sum_{k=1}^{n} m_k}{n}\right)}{f(d_{ij})} \tag{5}$$

where i, j, k are territorial area or units, m_k is »mass« in the k^{th} territorial unit, which in this case is the GDP; n is the number of territorial units included in the analysis and $f(d_{ij})$ is the resistance factor, function.

The effect of mass distribution in an arbitrary point of the space is the value-difference between the internal potential and the location potential at the given point:

$$U_i^{mass\,distribution} = BA_i - U_i^{location} \tag{6}$$

The effects of area size (Equation (7)) and own mass (Equation (8)) can be interpreted accordingly in the case of their own potentials (the signs are the same as above):

$$U_i^{area\,size} = \frac{\left(\frac{\sum_{i=1}^{n} m_i}{n}\right)}{f(d_{ii})} \tag{7}$$

$$U_i^{own\,mass} = SA_i - U_i^{area\,size} \tag{8}$$

where m_i is »mass« in the i^{th} territorial unit, which in this case is the GDP; n is the number of territorial units includd in the analysis, d_{ii} is the distance within the region, which is calculated in a way that the area of a region is considered to be circle. The radius of this circle is equal to the own distance. $f(d_{ii})$ is the resistance factor or function.

3.2 Results of potential analysis

According to our potential analysis, the region in the most favourable position (in regard to the overall potential) within the European Union is Paris, followed by Inner London and Hauts-de-Seine (Figure 7). In general, it can be concluded that regions in the most favourable positions are the central regions of France and the regions of South England, the Netherlands, Belgium, Switzerland, and North Italy, and West Germany. The potential decreases gradually from the indicated core areas towards the peripheries. Our results justify the Blue Banana spatial structural model (Brunet 1989) and its extension to a certain extent (Kunzmann 1992).

Let us review the effects of the potential components. Within the potential, the effect of spatial location reflects the core-periphery relations; that is, the effect keeps decreasing as we move away from the geographical centre (Figure 8). The effect of the position is positive in each case, meaning that it always contributes to the overall potential. The effect of spatial location is the most important component within the overall potential for each of the regions. This means that the basic spatial structural relations – demonstrable with the help of the potential model – are determined mostly by the core-periphery relations in Europe; and other, later described components are able to modify this basic structure only slightly. Out of the known spatial structural models, this form is most similar to the European Pentagon (ESDP 1999) (see Figure 2).

As for the mass distribution, the catchment areas of London and Paris are outstanding (Figure 9). The effect of mass distribution contributes to the overall potential, contrary to the previous component, both negatively and positively. Out of the 1,378 examined regions, in 833 cases the sign is negative, while it is positive in the remaining 545 cases.

The next two components (area size and the own mass of the given region) constitute the own potential part of the potential model. In the first case, we deal with the area size (Figure 10). Provided that the area of the given region is taken into consideration when calculating own potential (when we calculated own distance), the value of this component changes to the extent of the areas of the regions. The sign of

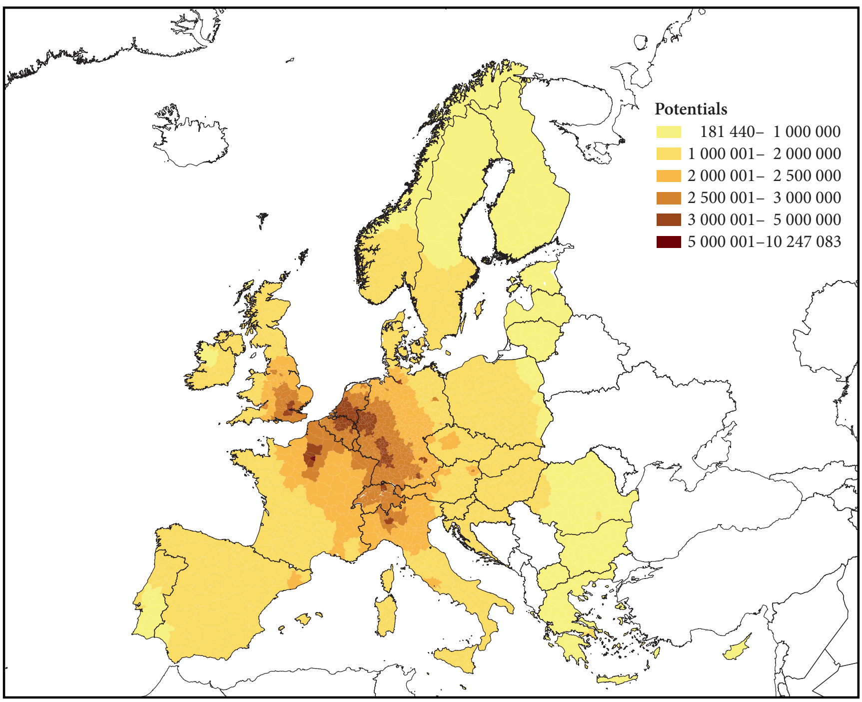

Figure 7: The potential values of regional GDP, 2008.

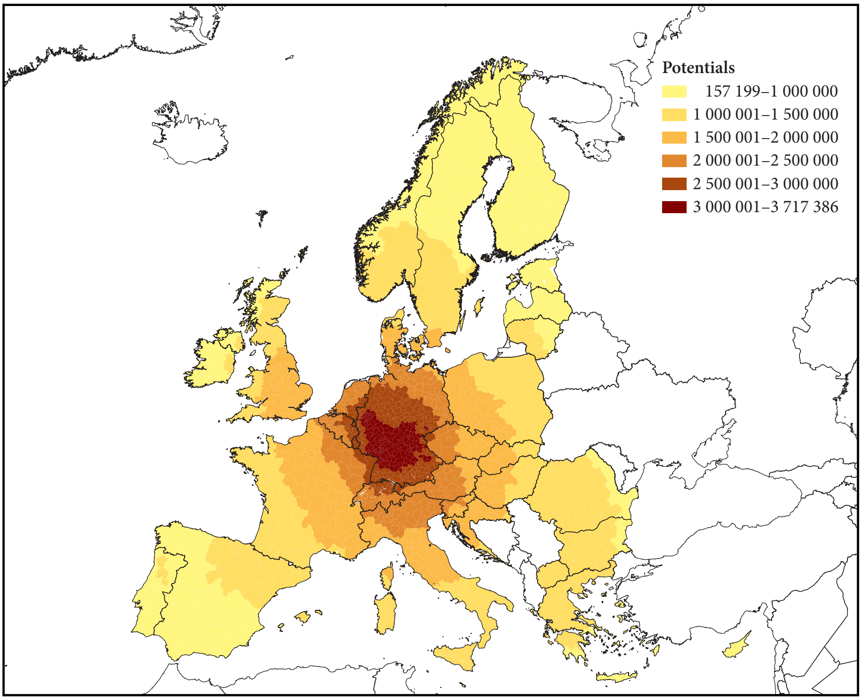

Figure 8: The role of spatial location in the potential values of the regional GDP.

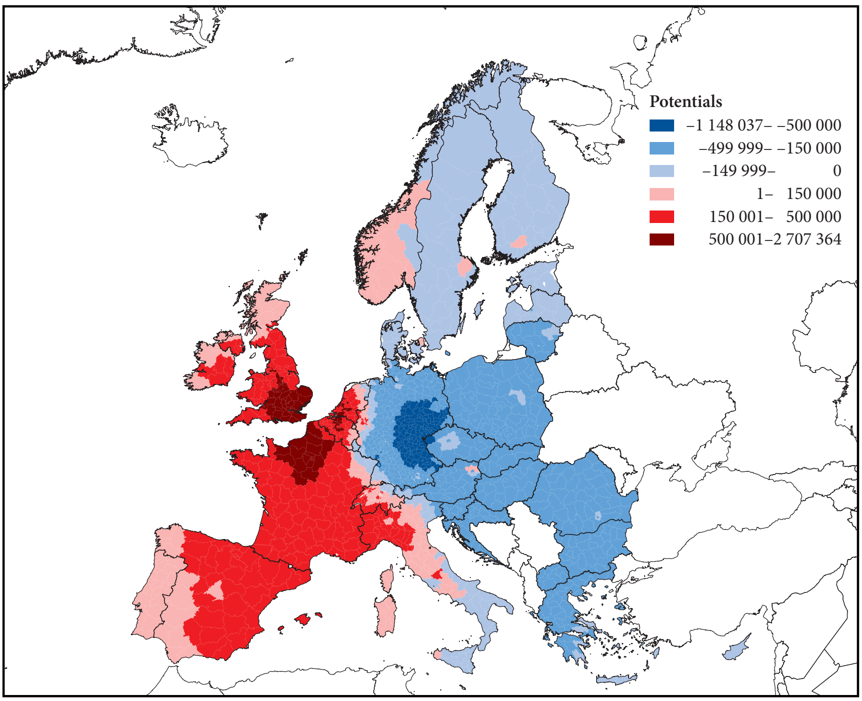

Figure 9: The role of mass distribution in the potential value of regional GDP.

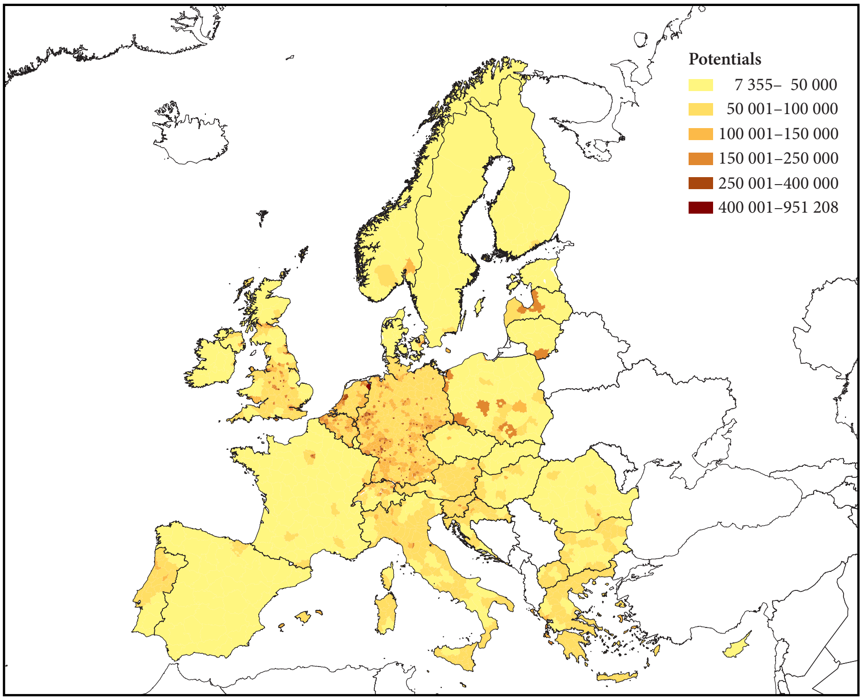

Figure 10: The role of area size in the potential value of regional GDP.

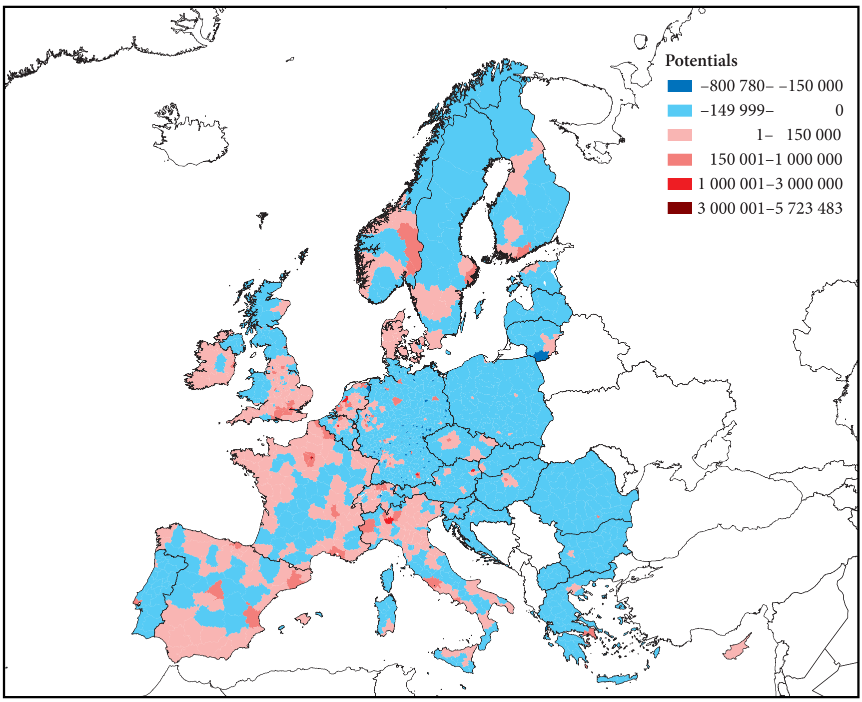

Figure 11: The role of own mass in the potential values of regional GDP.

the area size is always positive and its extent is inversely related to the area of the region. Thought we did not use population data, we can conclude that the value of this component refers primarily to urbanisation, since the regions with smaller area are big cities in most of the cases.

Finally, the last component is the own mass of the given region (Figure 11). Its sign can also be either negative or positive.

In total, we can conclude that the different spatial structural models available in the literature can be synthetised by dividing the potential models into parts. The division into axes and zones can be shown in the analyses of spatial position and mass distribution, while the polycentric view can be linked to area size and to own mass. They visualise the real space structure side by side, complementing each other. By dividing the potential models into parts, the above described spatial structural ideas that are present in the space at the same time can be standardised.

3.3 Gravity models and examination of the spatial structure

After separating the potential models as described above, the other approach to examine spatial structure is about gravity models that are based on the application of forces. With the approach that we present here, one can assign attraction directions to the given territorial unit. This method complements and specifies the view of spatial structure described by the potential models.

The law of general mass attraction, Newton's law of gravitation (1686), states that any two point masses attract each other by a force that is proportional to the product of the two masses (these are heavy and not powerless masses) and is inversely proportional to the square of the distance between them (Budó 1970):

$$F = \gamma \cdot \frac{m_1 \cdot m_2}{r^2} \tag{9}$$

where the proportionality measure γ is the gravitational constant (regardless of space and time).

If the radius vector from point mass 2 to point mass 1 is signed with r, then the unit vector from point 1 to point 2 is –***r*** and therefore the gravitational force applied on point mass 1 due to point mass 2 is:

$$\vec{F}_{1,2} = -\gamma \cdot \frac{m_1 \cdot m_2}{r^2} \cdot \frac{\vec{r}}{r}$$ (10) (MacDougal 2013)

A gravitational force field is definite if the direction and the size of the field strength (K) can be defined at each point of the given field. To do so, provided that K is a vector, three pieces of data are necessary in each point (two in the case of a plain), such as the rectangular components Kx, Ky, Kz of the field strength as the function of the place. Many force fields, however, like the gravitational force field, can be described in a much simpler way, that is, instead of three, using just one scalar function, the so-called potential (Figure 12) (Budó 1970).

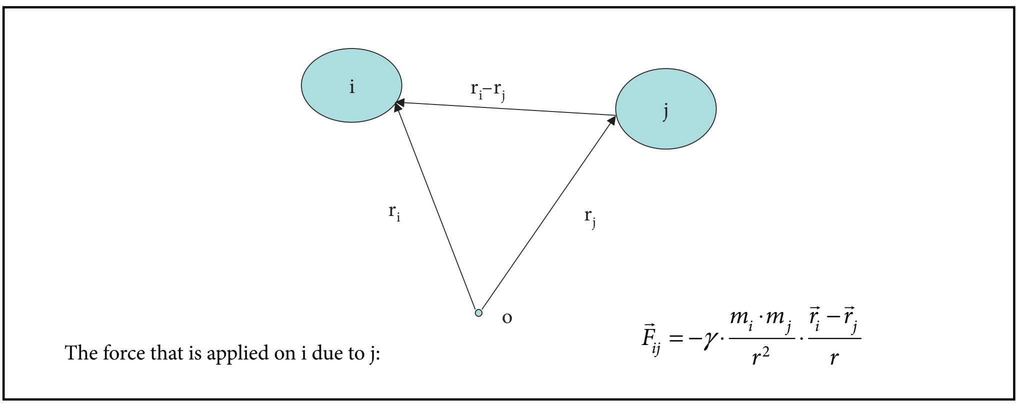

Figure 12: Calculation of the gravitational force.

Potential is similarly related to field strength than force or potential force to strength. If in the gravitation field of K field strength, the trial mass, on which a force of $\boldsymbol{F} = m\boldsymbol{K}$ is applied, is moved to point B from point A by force $-\boldsymbol{F}$ (without acceleration) along with some curve, then work of $L = -\int_A^B F_s ds$ has to be done against force $\boldsymbol{F}$ based on the definition of work. This work is independent of the curve from A to B. Therefore it is the change of the potential energy of an arbitrary trial mass: $L = E_{potB} - E_{potA} = -\int_A^B F_s ds = -m\int_A^B K_s ds$. By dividing by m, the potential difference between points B and A in the gravitational space is:

$$U_B - U_A = -\int_A^B K_s ds.$$

By utilizing this relation, in most of the social scientific applications of the gravitational model the space primarily was intended to be described by only one scalar function (see for example the potential model) (Kincses and Tóth 2011), while in the gravitational law, it is mainly the vectors characterizing the space that have an important role. The main reason for this is that the arithmetic operations with numbers are easier to handle than calculations with vectors. In other words, for work with potentials, solving the problem also means avoiding calculation problems.

Even if potential models often show properly the concentration focus of the population or GDP and the space structure, they are not able to provide any information on the direction towards which the social attribute of the other regions attract a specified region and on the force with which they attract it.

Therefore, by using vectors we are trying to demonstrate in which direction the European regions (NUTS1, 2, and 3) are attracted by other regions in the economic space compared to their real geographical position. With this analysis, it is possible to reveal the centres and fault lines representing the most important areas of attractiveness and it is possible to visualise the differences among the gravitational orientation of the regions, which we will describe in more detail in a later section. First of all, let us look at the method.

In the traditional gravitational model (Stewart 1948) the »population force« between i and j are expressed in D_{ij}, where W_i and W_j are the populations of the settlements (regions), d_{ij} is the distance between i, and j and g is the empirical constant:

$$D_{ij} = g \cdot (\frac{W_i \cdot W_j}{d_{ij}^2}) \tag{11}$$

With the generalisation of the above formula, the following relationship is given in Equation (12) and (13):

$$D_{ij} = \left|\vec{D}_{ij}\right| = \frac{W_i \cdot W_j}{d_{ij}^c} \tag{12}$$

$$\vec{D}_{ij} = -\frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot \vec{d}_{ij} \tag{13}$$

where W_i and W_j indicate the masses taken into consideration, d_{ij} is the distance between them and c is the constant, which is the change in the intensity of the inter-territorial relations as a function of the distance. With the increase of the power, the intensity of the inter-territorial relations becomes more sensitive to the distance and at the same time, the importance of the masses gradually decreases (see Dusek 2003).

With this extension of the formula, not only the force between the two regions but also its direction can be defined. In the calculations, it is worth dividing the vectors into x and y components, and then summarising them separately. In order to calculate this effect (the horizontal and vertical components of the forces), the necessary formulas can be deducted from Equation 14:

$$D_{ij}^X = \frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (x_i - xj) \tag{14}$$

$$D_{ij}^{Y} = \frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (y_i - y_j) \tag{15}$$

where x_i, x_j, y_i, y_j are the centroids of regions i and j.

If, however, the calculation is carried out for each region included in the analysis, the direction and the force of the effect on the given territorial unit can be defined using Equation (16) and (17):

$$D_{ij}^{X} = -\sum_{j=1}^{n} \frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (x_i - x_j) \tag{16}$$

$$D_{ij}^{Y} = -\sum_{j=1}^{n} \frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (y_i - y_j) \tag{17}$$

With these equations, in each territorial unit, the magnitude and the direction of the force due to the other regions can be defined. The direction of the vector assigned to the regions determines the attraction direction of the other regions, while the magnitude of the vector is related to the magnitude of the force. In order to make visualisation possible, the forces are transformed to proportionate movements in Equation (18) and (19):

$$x_i^{\mathrm{mod}} = x_i + \left(D_{ij}^{X} \cdot \frac{x^{\max}}{x^{\min}} \cdot k \frac{1}{\frac{D_{ij}^{X\max}}{D_{ij}^{X\min}}} \right) \tag{18}$$

$$y_i^{\mathrm{mod}} = y_i + \left(D_{ij}^{Y} \cdot \frac{y^{\max}}{y^{\min}} \cdot k \frac{1}{\frac{D_{ij}^{Y\max}}{D_{ij}^{Y\min}}} \right) \tag{19}$$

where X_i mod and Y_i mod are the coordinates of the new points modified by gravitational force, x and y are the coordinates of the original point set, their extreme values are x_{max}, y_{max}, a x_{min}, y_{min}, D_{ij} are the forces along the axes and k is constant, in this case its value is 0.5. We got this value as a result of an iteration procedure.

Then it is worth comparing the new point set with the original one. This can naturally be done with visualisation, but in the case of such a large number of points, this alone probably does not provide a really promising result. Much more favourable results can be obtained by applying bidimensional regression analysis (see the equations related to the Euclidean version in Table 1).

Where x and y refers to the coordinates of the independent form, a and b sign the coordinates of the dependent form, a' and b' are the coordinates of the independent form in the dependent form. α_1 refers to the extent of the horizontal shift, while α_2 defines the extent of the vertical shift. β_1 and β_2 are used to determine the scale difference (Φ) and Θ is the rotation angle. SST is total sum of squares, SSR is sum of squares due to regression, SSE is explained sum of squares of errors/residuals that is not explained by the regression).

To visualise the bidimensional regression, the Darcy program can be useful (D'arcy 1917). The grid fitted to the coordinate system of the dependent form and its interpolated modified position make it possible to further generalise the information about the points of the regression.

The arrows in Figure 13 show the direction of movement and the grid colour refers to the nature of the distortion. Warm colours indicate divergence; that is, the movements in the opposite direction, which can be considered to indicate the most important gravitational fault lines. Areas indicated with green and its shades refer to the opposite, namely to the concentration, to the movements in the same directions (convergence), which can be considered to be the most important gravitational centres.

Our analysis can be carried out at the NUTS1, 2, and 3 levels. The comparison of the results with those of bidimensional regression can be found in Table 2.

Table 1: The equations of the bidimensional Euclidean regression.

1. The regression equation	$\begin{pmatrix} A^{'} \\ B^{'} \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} + \begin{pmatrix} \beta_1 & -\beta_2 \\ \beta_2 & \beta_1 \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \end{pmatrix}$
2. Scale difference	$\Phi = \sqrt{\beta_1^2 + \beta_2^2}$
3. Rotation	$\Theta = \tan^{-1}\left(\frac{\beta_2}{\beta_1}\right)$
4. β_1	$\beta_1 = \frac{\sum (a_i - \bar{a}) \cdot (x_i - \bar{x}) + \sum (b_i - \bar{b}) \cdot (y_i - \bar{y})}{\sum \left(x_i - \bar{x}\right)^2 + \sum (y_i - \bar{y})^2}$
5. β_2	$\beta_2 = \frac{\sum (b_i - \bar{b}) \cdot (x_i - \bar{x}) - \sum (a_i - \bar{a}) \cdot (y_i - \bar{y})}{\sum (x_i - \bar{x})^2 + \sum (y - \bar{y})^2}$
6. Horizontal shift	$\alpha_1 = \bar{a} - \beta_1 \cdot \bar{x} + \beta_2 \cdot \bar{y}$
7. Vertical shift	$\alpha_2 = \bar{b} - \beta_2 \cdot \bar{x} - \beta_1 \cdot \bar{y}$
8. Correlation based on the error terms	$\alpha_2 = \bar{b} - \beta_2 \cdot \bar{x} - \beta_1 \cdot \bar{y}$
9. The resolution difference of a square sum	$\sum\left[(a_i - \bar{a})^2 + (b_i - \bar{b})^2\right] = \sum\left[(a_i' - \bar{a})^2 + (b_i' - \bar{b})^2\right] + \sum\left[(a_i - a_i')^2 + (b_i - b_i')^2\right]$ $\mathrm{SST} = \mathrm{SSR} + \mathrm{SSE}$
10. A'	$A' = \alpha_1 + \beta_1(X) - \beta_2(Y)$
11. B'	$B' = \alpha_2 + \beta_2(X) + \beta_1(Y)$

Source: Tobler (1994) and Friedman–Kohler (2003) cited by Dusek 2011, 14.

Table 2: Bidimensional regression between gravitational and geographical spaces.

Level	r	α1	α2	β1	β2	Φ	Θ	SST	SSR	SSE
NUTS1	0.91	0.19	0.69	0.99	0.00	0.99	0.00	20 430	19 849	582
NUTS2	0.97	0.04	0.15	1.00	0.00	1.00	0.00	54 121	53 484	638
NUTS3	0.99	0.13	–0.04	1.00	0.00	1.00	0.17	139 884	139 847	37

As the results show, the lower the level that is used for the analysis, the smaller the deviation of the gravitational point form is from the original structure. This is proven by the correlation and by the sum of squared deviations and their components. Because of the mass differences among the regions, the analysis carried out at different territorial levels shows results that are different in their nature even if they are similar in many aspects of their basic structure. That is why we decided to carry out the analysis at each territorial level in order to examine the different levels of the spatial structure. We visualised our results, and we drew the following conclusions.

The analysis carried out at the NUTS1 level contains only the most general relations. These general relations, however, are not sufficient to carry out a deeper analysis of the spatial structure. That is why it is necessary to go on to the NUTS2 level. In this case, as shown in Figure 13 regional concentrations can unambiguously be seen, and we consider these to be the core regions. Based on the analysis carried out at the NUTS2 level, basically three gravitational centres, slightly related to each other, can be found in the European space. Gravitational centres are the regions that attract other regions and the gravitational movement is toward them. These three centres or cores are (Figure 13):

- the region including Baden-Württemberg, the western part of Austria, and the eastern part of Switzerland;
- the region including the Benelux countries and the western part of Nordrhein-Westfalen;
- the region including most of England. Mainly these core areas have an effect on the regions of the examined area.

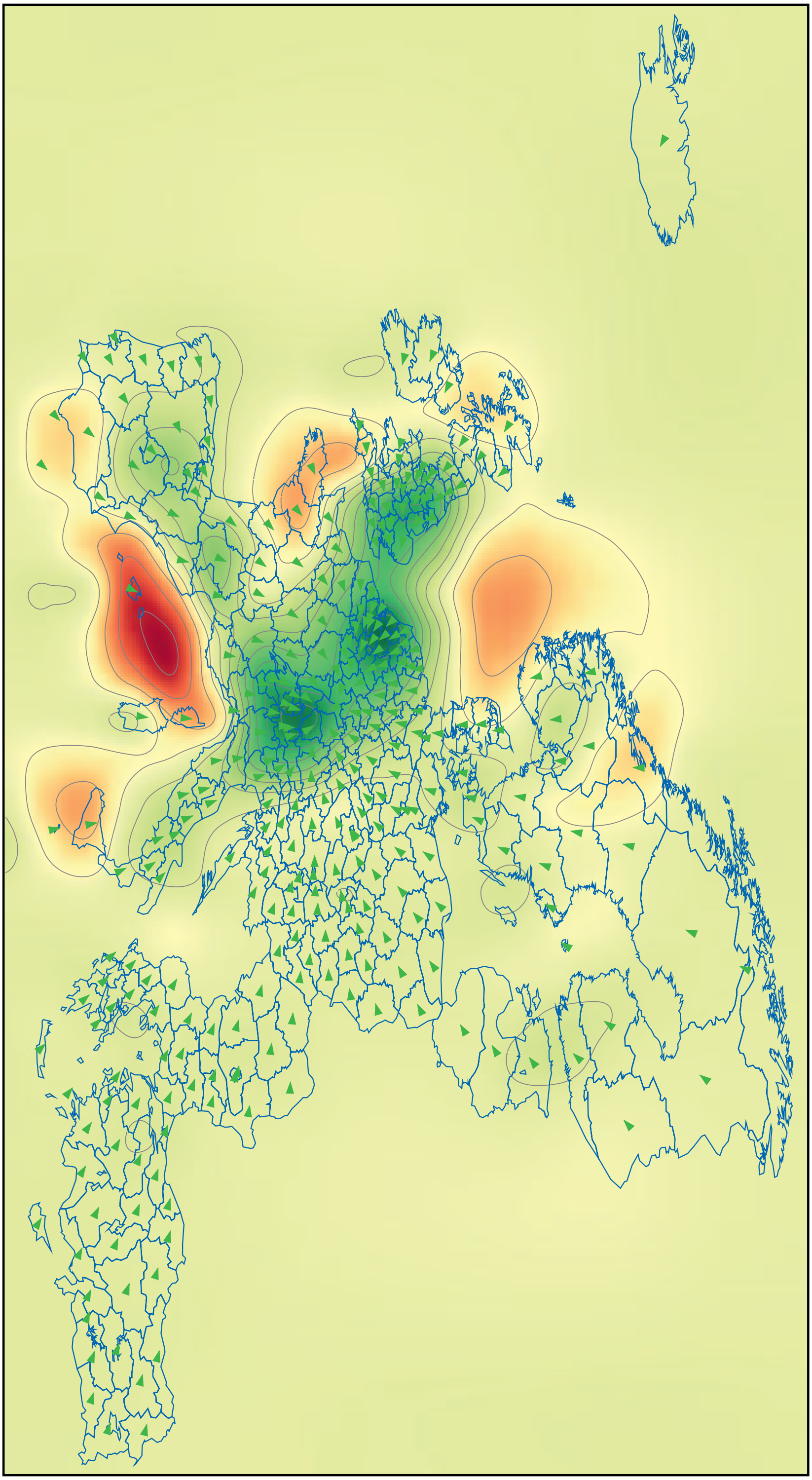

Figure 13: Directions of the distortion of gravitational space compared to geographical space for the European regions (NUTS2).

The three centres also include two concentration spurs. The stronger and without any doubt the more important one extends from the eastern part of Switzerland through south France to Madrid, while the other and somewhat weaker one starts from this point and goes through the Apennine Peninsula.

4 Comparison of the applied methods

The methods applied in this study used the same data and yielded different results. The comparison of the results methodologically is relatively difficult. Defining the core regions is easiest using the gravity analysis, provided that these are the regions that have converging spatial movements and that can be considered the main gravitational centres. These regions are shown in green in Figure 13. In case of the moving average and the potential method, the situation is a bit harder. In these cases, based on our data, the regions belonging to the upper quarter of the data series were considered core areas. The visualised comparison based on this can be seen in Figure 14.

We can conclude that there are core regions based on each method that are not considered core regions on the basis of the other methods. In the case of the moving average, these are the Northern European regions, in the case of the potential method, it is Berlin, while in the case of the gravitational method, these are the southern French and northern Spanish regions. The intersection of the three models, however, can be seen, which definitely verifies the banana shape. The European core area, based on our analysis, still has the banana shape, like other authors concluded, but the different analyses highlight the existence of related regions that are moving to catch up. In order to verify our statement, however, further time series analysis is also necessary, which can be the research topic of another study.

Furthermore, one of the most important results of our research is that the strongest determining element of the spatial structure is the spatial position component, obtained from the separation of the potential, which expresses the basic core–periphery relations. The other components can only slightly modify its effect; therefore the basic spatial relations can only be improved slightly by development tools.

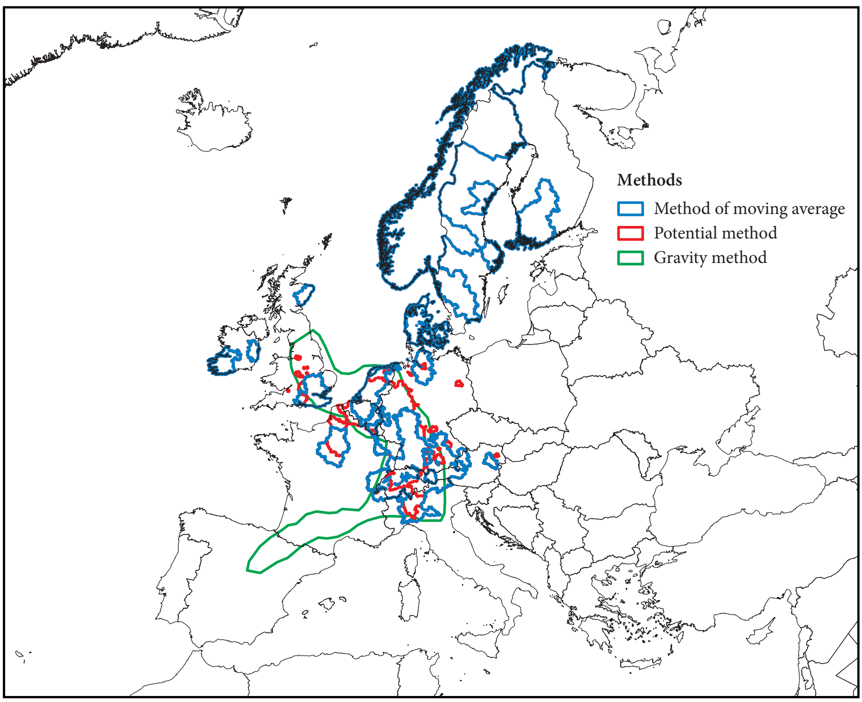

Figure 14: Comparison of the results of the three methods.

5 Acknowledgement

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Prostorske strukture v Evropi

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IZVLEČEK: Cilj študije je opis prostorske strukture Evrope s krajevno drsečim povprečjem, modelom možnosti in dvodimenzionalne regresijske analize, temelječe na težnostnem modelu. Prostorsko strukturo Evrope opisuje veliko teoretičnih in praktičnih del. V literaturi se pojavljajo delno območja, osi in formacije, delno pa policentrični modeli. Nekatere od teh navajamo, brez trditev o popolnosti (kar bi lahko bila tema druge študije). Tudi po naših opažanjih so vidni obrisi struktur, ki jih v članku opisujemo. Umestitev jedra držav Evropske unije jasno opravičuje obliko banane in na njo se na več območjih navezujejo ostale, dohitevajoče jo regije.

KLJUČNE BESEDE: geografija, prostorske strukture, drseče povprečje, potencialni model, težnostni model, dvodimenzionalna regresija, BDP, Evropa

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Vsebina

1 Uvod

V zadnjih desetletjih je bilo precej poskusov odkrivanja in vizualizacije raznolike gospodarske in socialne podobe Evrope. Ti modeli skušajo prikazati odločilne elemente geografskega prostora, kompleksnih sistemov in značilnosti struktur teh prostorov. Prostorske strukturne vizualizacije temeljijo na dveh pristopih: prva vključuje območja, osi in formacije, druga pa policentrične modele.

Prva provokativna oblika je bila objavljena v Brunetovi študiji (1989) kot »evropska hrbtenica«. Kasneje se je je prijelo ime »modra banana« (ang. *Blue banana*). Za predstavitev jedra gospodarskega območja so avtorji obkrožili območje v obliki banane, ki sega približno od Liverpoola do Nice ali od Londona do Milana (slika 1). Naše slike predstavljajo – brez kakršnih koli trditev o popolnosti – pristope, za katere menimo, da so najpomembnejši.

Slika 1: Modeli I krajevne strukture (vir: lastna izdelava po Brunet 1989, Gerzelak 1996, Kunzmann 1992, Schatzl 1993, Hospers 2002).
Glej angleški del prispevka.

Banani podobno obliko lahko najdemo tudi na vzhodu srednje Evrope. Pravimo ji srednjeevropski bumerang (ang. *Central European boomerang*; glej sliko 1). Po Gorzelaku (1996) so za to območje, ki se razteza od Gdanska do Budimpešte in vključuje Poznan, Wroclaw, Parago in trikotnik Dunaj–Bratislava–Budimpešta, odločilnega pomena glavna mesta, resnični kraji razvoja.

Slika 2: Modeli II krajevene strukture (vir: lastna izdelava po van der Meeru 1998 in ESDP 1999).
Glej angleški del prispevka.

Nadaljnjaoblika, ki se pojavlja v literaturi, je »rdeča hobotnica« (ang. *Red octopus*), katere telo in zahodne lovke se raztezajo med Birminghamom in Barcelono, ter proti Rimu in Parizu. Na severu se raztezajo v smeri Copenhagen–Stockholm (Helsinki), na vzhodu pa v smeri Berlin–Poznan–Varšava ter Praga–Dunaj–Budimpešta (van der Meer 1998; slika 2). Za razliko od zgodnejših vizualizacij ta oblika vključuje skupino razvitih območji in njihova jedrna mesta s poudarkom na možnostih zmanjšanja prostorskih razlik, kot tudi z vizualizacijo policentričnosti in evrokoridorjev (Szabó 2009). »Modra zvezda« (ang. *Blue star*) je temu nekoliko podobna. Čeprav ni postala tako priljubljena, »modra zvezda« prav tako nakazuje smeri razvoja in dinamiko območij s puščicami in je zato primerna za nadaljnje analize. (Dommergues 1992; slika 3).

Slika 3: Model III krajevne strukture (vir: lastna izdelava po Dommergues 1992). Leta 1999 je v Evropski prostorski razvojni perspektivi (European spatial development perspective – ESDP) območje med Londonom, Parizom, Milanom, Münchnom in Hamburgom, opredeljeno kot »evropski pentagon«.
Glej angleški del prispevka.

Slika 4: Model IV krajevne strukture (vir: lastna izdelava po Kunzmann 1992).
Glej angleški del prispevka.

Druga pomembna skupina za vizualizacijo prostorske strukture poudarja urbani razvoj, dinamične spremembe urbanih območij in policentrično prostorsko strukturo (eno od teh lahko vidimo na sliki 4). Kunzmann in Wegener (Kunzmann in Wegener 1991; Kunzmann 1992; 1996; Wegener in Kunzmann 1996) se nista strinjala s prostorskim opisom »modre banane« in drugimi oblikami. Prepričana sta bila, da mestna območja ne ležijo samo znotraj modre banane, temveč v grozdih (ang. *Bunch of grapes*) in tako določajo policentrično strukturo Evrope. Policentričnost je postala ena bolj priljubljenih tem in eden od ključnih elementov Evropske prostorske razvojne perspektive iz leta 1999. Eden od razlogov za krepitev policentričnih značilnosti je ta, da je bil za 90-a leta 20. stoletja za Evropo značilen proces prostorske koncentracije.

Ta struktura se kaže tudi v tako imenovanih MEGA območjih (Nordregio 2004), ki prav tako poudarjajo kompleksnost Evropske prostorske strukture kot tudi vizualizacijo jedrnih območij; prav tako pa poudarjajo naraščajočo razliko med mesti in podeželjem.

Z uporabo treh metod in s pomočjo prostorskih modelov, ki vsak zase predstavlja drugačen pristop k problemu, bomo v naslednjih poglavjih podrobneje preučili ozadje relacij prostorskih struktur in zgoraj opisanih modelov. V vseh primerih kot odločilno mero za prostorski razvoj uporabljamo vrednosti BDP-ja, saj menimo, da njegova uporaba omogoča podrobno analizo krajevne strukture.

2 Krajevno drseče povprečje

Metodo krajevnega drsečega povprečja je mogoče uporabiti za analizo krajevnih pojavov in osnovne strukture (Dusek 2001). Cilj naše analize je bilo razkritje močnejših relacij s pomočjo krajevnega drsečega povprečja. To je mogoče storiti z iskanjem ustrezne agregacije. Z dano osnovno enoto lahko izračunamo krajevno drseče povprečje opazovanih značilnosti s povprečji okoliških območij, na podlagi danih topoloških značilnosti po enačbi 1 (Haining 1978):

$$M(x_i) = \frac{\Sigma(f_j \cdot x_j)}{\Sigma f_j} \qquad (1)$$

za elemente, kjer $d(x_i;x_j) \leq m$ in kjer je $M(x_i)$ drseče povprečje točke i, $d(x_i, x_j)$ je razdalja med središčema območij i in j in m radij drsečega povprečja. x_j se nanaša na vrednost, ki se povpreči in pripada j-temu opazovanju, to je BDP na prebivalca in f_j je frekvenca oziroma teža, ki pripada j-temu opazovanju. Če se računa drseče povprečje BDP na prebivalca, je to število prebivalstva.

V tem primeru je raven agregacije opredeljena tako, da zagotavlja njeno povezanost z obravnavano teritorialno ravnjo. V naši analizi je to raven NUTS1. Ta teritorialna raven je izmerjena pri povprečnem radiju ob predpostavki, da ima povprečno območje NUTS1 regij obliko kroga s polmerom 70 km. Naše izračune smo sprva izvedli na polmeru 70 km, vendar smo ocenili, da rezultati dajejo še vedno preveč razdrobljeno podobo. Domnevamo, da je razlog za to relativno velika razpršenost med območji NUTS1 ravni, zato se nam je zdelo primerneje povečati radij drsečega povprečja 100 km. Izračun smo nazadnje izvedli za vsakih 20 km za radije med 100 in 200 km. Razlog za povečevanje radija je, da se z višanjem stopnje agregacije zvišuje tudi abstrakcija, čeprav se po določeni velikosti povečuje tudi izguba informacij.

Tako dobljen zemljevid (slika 5) je v primerjavi z osnovnimi podatki veliko manj razdrobljen, kar zagotavlja izvedbo podrobnejše analize. Na podlagi zemljevida lahko ugotovimo, da se na obravnavanem območju, območja z najugodnejši pozicijo v Evropi, pojavljajo kot otoki – motorji ekonomije. To so predvsem nekatera območja južne province Nemčije, regije Rima in severne Italije, severni del Švice, velik del Avstrije, aglomeracije Londona in Pariza, večji del držav Beneluksa in Danske, in jedro območja, ki vključuje velik del Skandinavskih držav. Poleg teh lahko izstopajoče vrednosti najdemo samo še na nekaterih območjih kot so: južna Irska (O'Reilly 2004), severna Španija (Baskija) in južna Škotska. V primeru vzhodnoevropskih območij je odločujoč učinek železne zavese. V teh krajih izstopajo iz okolice predvsem aglomeracije glavnih mest (predvsem Bratislava), čeprav je zaostanek za zgoraj omenjenimi območji precejšen. Med državami nekdanjega socialističnega bloka jih ima le nekaj možnost, da se poveže z omenjenim osrednjimi območji. V tem kontekstu lahko kot pozitivne primere izpostavimo le nekatere regije v Sloveniji (predvsem Ljubljana; glej Ravbar, Bole in Nared 2005) in na Češkem.

Z zgoraj opisanim povečevanjem radija smo povečali stopnjo abstrakcije. Z vsakim povečanjem radija za 20 km so rezultati postajali bolj očitni. Izstopajoča območja so izolirana od svoje okolice, zato so se glavni centri kristalizirali. Rezultati 200-kilometrskega radija so prikazani na sliki 6.

Slika 5: Krajevno drseče povprečje BDP-ja na prebivalca (2008) izračunano na 100 km radiju.
Glej angleški del prispevka.

Slika 6: Krajevno drseče povprečje BDP-ja na prebivalca (2008) izračunano na 200 km radiju.
Glej angleški del prispevka.

3 O težnostnih in potencialnih modelih

3.1 Povezava med prostorom in utežjo, ki ločuje potencial

Ena od najbolj pogosto uporabljenih metod za preučevanje prostorske strukture v literaturi je potencialni model. Splošna formula za potencialne modele je podana v enačbi (2) (glej npr. Hansen 1959):

$$A_i = \sum_j D_j \cdot F(c_{ij}) \tag{2}$$

kjer je A_i potencial območja *i* (območja NUTS3), D_j masa območja, *j*, c_{ij} razdalja med središčema območij *i* in *j* (premočrtna razdalja) in *F(cij)* faktor upora. Potencial je vsota lastnega potenciala in notranjih potencialov (Pooler 1987) po enačbi (3):

$$\sum A_i = SA_i + BA_i \tag{3}$$

kjer je ΣA_i skupni potencial območja *i*, SA_i lastni potencial in BA_i notranji potencial. Vrednost potenciala v dani točki je torej vsota notranjega in lastnega potenciala oziroma vsota lastne mase in vpliva lastne velikosti območja. Lastni potencial se nanaša na vpliv območja in na lastni potencial, medtem ko notranji potencial kaže vpliv vseh ostalih območij na potencial območja i.

Glede na topologijo geometrije potencialnih modelov lahko – ne glede na to kateri model uporabimo – sklenemo, da je skupna točka vseh, da merijo učinek pozicije razpona prostora in velikosti porazdelitve mas, kot je opisano v enačbi (4). Položaj razpona prostora je v bistvu opredeljen z geografsko pozicijo. To pomeni, da je za dano vrednost potenciala nemogoče vedeti ali je posledica ugodne oziroma neugodne (naselbinske, območne) strukture, položaja ali mas, velikosti območja ali učinka lastne mase. Zato smo učinke ločili in opisali deleže celotnih potencialnih vrednostih, ter uvedlii teritorialne razlike:

$$\sum A_i = BA_i + SA_i = U_i^{mass distribution} + U_i^{location} + U_i^{mass weight} + U_i^{area size} \tag{4}$$

V poljubni točki v prostoru se učinek potenciala, izpeljan iz prostorske lokacije, nanaša na vrednost pod pogojem, da so mase vseh navedenih teritorialnih enot enake, kot v enačbi 5:

$$U_i^{location} = \sum_j \frac{\left(\frac{\sum_{k=1}^{n} m_k}{n}\right)}{f(d_{ij})} \tag{5}$$

kjer so i, j in k teritorialna območja ali enote, m_k je masa k-te teritorialne enote, ki je v našem primeru pomeni BDP; *n* je število teritorialnih enot vključenih v analizo, $f(d_{ij})$ pa je faktor upora.

Učinek porazdelitve mas v poljubni točki prostora je razlika vrednosti med notranjim potencialom in prostorskim potencialom v dani točki:

$$U_i^{mass distribution} = BA_i - U_i^{location} \tag{6}$$

Učinke velikosti območij (enačba 7) in lastne mase (enačba 8) lahko ustrezno razložimo na primeru njihovih lastnih potencialov (oznake so enake kot zgoraj):

$$U_i^{area size} = \frac{\left(\frac{\sum_{i=1}^{n} m_i}{n}\right)}{f(d_{ii})} \tag{7}$$

$$U_i^{own mass} = SA_i - U_i^{area size} \tag{8}$$

kjer je m_i masa v *i*-ti teritorialni enoti, v tem primeru BDP; *n* je število teritorialnih enot zajetih v analizi, d_{ij} je razdalja znotraj krožnega območja, katerega radij je enak lastni razdalji, $f(d_{ij})$ pa je faktor ali funkcija upora.

3.2 Rezultati analize potencialov

Glede na našo analizo potencialov je v najbolj ugodnem položaju glede na celoten potencial v Evropski uniji območje Pariza, sledijo mu notranji London in Hauts-de-Seine (slika 7). Sklenemo lahko, da so v najbolj ugodnem položaju osrednja Francije in južna Anglija, Nizozemska, Belgija, Švica in severna Italija ter zahodna Nemčija. Potencial upada od navedenih območji proti obrobjem. Naši rezultati potrjujejo prostorsko strukturo modre banane (Brunet 1989) in do neke mere tudi njen podaljšek (Kunzmann 1992).

Slika 7: Potencialne vrednosti regijskega BDP, 2008.
Glej angleški del prispevka.

Poglejmo še učinek potencialnih komponent. Znotraj potenciala odraža učinek prostorske lokacije razmerje med jedrom in obrobjem; torej se učinek zmanjšuje z oddaljevanjem od geografskega centra (slika 8). Učinek lege je v vsakem primeru pozitiven, kar pomeni, da vedno prispeva k celotnemu potencialu. Za vsa območja je učinek prostorske lokacije torej najpomembnejša komponenta znotraj celotnega potenciala. To pomeni, da so temeljne prostorske strukturne relacije v Evropi – dokazljive s potencialnim modelom – določene predvsem z razmerjem med jedrom in obrobjem. Ostale, pozneje opisane strukture, lahko osnovno stukturo le nekoliko spremenijo. Od znanih prostorskih modelov je ta oblika najbolj podobna evropskemu pentagonu (ESDP 1999) (glej sliko 2).

Slika 8: Vloga prostorske lokacije v potencialnih vrednostih regijskega BDP.
Glej angleški del prispevka.

Kar zadeva porazdelitve mase sta izjemi območji Londona in Pariza (slika 9). Učinek porazdelitve mase prispeva k celotnemu potencialu, v nasprotju s prejšnjo komponento, tako pozitivno kot negativno. Od 1,378 pregledanih območij, je v 833-ih primerih predznak negativen in pozitiven v preostalih 545 primerih.

Slika 9: Vloga porazdelitve mase v potencialnih vrednostih regijskega BDP.
Glej angleški del prispevka.

Naslednji dve komponenti (velikost območja in lastna masa dane regije) predstavljata lastni potencial potencialnega modela. V prvem primeru imamo opravka s površino območja (slika 10). Če upoštevamo, da je pri izračunu lastnega potenciala upoštevana površina dane regije (ko smo izračunali lastno razdaljo), se vrednost te komponente spreminja v obsegu površin regij. Predznak velikosti območja je vedno pozitiven in njen obseg je v obratnem sorazmerju s površino območja. Čeprav nismo uporabili podatkov o prebivalstvu, lahko sklenemo, da se vrednost te komponente nanaša predvsem na urbanizacijo, saj so območja z manjšo površino povečini velika mesta.

Slika 10: Vloga velikosti regije v potencialnih vrednostih regijskega BDP.
Glej angleški del prispevka.

Slika 11: Vloga lastne mase v potencialnih vrednostih regijskega BDP.
Glej angleški del prispevka.

Zadnja komponenta je lastna masa dane regije (slika 11). Njen predznak je lahko ali pozitiven ali negativen. Sklenemo lahko, da različne krajevne strukturne modele, ki jih najdemo v literaturi, lahko sintetiziramo z razdelitvijo potencialnih modelov. Delitev na osi in območja lahko prikažemo z analizo prostorske pozicije in razporeditve mase, medtem ko policentričen pogled lahko povežemo z velikostjo regije in lastno maso. Druga ob drugi ponazarjata resnično prostorsko strukturo in se dopolnjujeta. Z delitvijo potencialnih modelov lahko standardiziramo zgoraj opisane ideje o prostorskih strukturah, ki so istočasno prisotne v prostoru.

3.3 Težnostni modeli in pregled prostorske strukture

Po zgoraj opisani ločitvi potencialnih modelov je na vrsti pristop k obravnavi prostorskih struktur z gravitacijskimi modeli, ki temeljijo na uporabi sil. S pristopom, ki ga bomo predstavili tukaj, lahko priredimo smeri privlačnosti dani teritorialni enoti. Ta metoda dopolnjuje in specificira pogled na prostorske strukture, opisane s potencialnimi modeli.

Splošni, Newtonov gravitacijski zakon (1686) pravi, da se katerikoli dve masni točki privlačita s silo, ki je sorazmerna s produktom njunih mas in obratno sorazmerna kvadratu razdalje med njima (Budó 1970):

$$F = \gamma \cdot \frac{m_1 \cdot m_2}{r^2} \tag{9}$$

kjer je mera proporcionalnosti γ gravitacijska konstanta (ne glede na prostor in čas). Če je krajevni vektor iz masne točke 2 do masne točke 1 r, potem je enotski vektor iz točke 1 do točke 2 –r, torej je gravitacijska sila na masno točko 1 zaradi masne točke 2 enaka:

$$\vec{F}_{1,2} = -\gamma \cdot \frac{m_1 \cdot m_2}{r^2} \cdot \frac{\vec{r}}{r} \qquad \text{(10) (MacDougal 2013)}$$

Polje gravitacijske sile je določeno, če lahko v vsaki točki polja definiramo smer in jakost polja (K). Če je K vektor, za to potrebujemo tri podatke (dva v primeru ravnine), kot pravokotne komponente Kx, Ky in Kz jakosti polja kot funkcije prostora. Jakostna polja, kot je gravitacijsko polje, lahko opišemo na veliko enostavnejši način, torej namesto treh z uporabo samo ene skalarne funkcije, tako imenovanega potenciala (slika 12; Budó 1970).

Slika 12: Izračun gravitacijske sile.
Glej angleški del prispevka.

Povezava med potencialom in jakostjo polja je podobna povezavi med silo oziroma potencialno silo in jakostjo. Če v gravitacijskem polju jakosti K premaknemo testno maso, na katero deluje sila $F = mK$, iz točke A v točko B s silo ***–F*** (brez pospeška), po neki krivulji moramo opraviti delo $L = -\int_A^B F_s ds$ proti sili F po definiciji za delo. Delo je neodvisno od krivulje A–B, torej je sprememba potencialne energije neke poljubne testne mase enaka: $L = E_{potB} - E_{potA} = -\int_A^B F_s ds = -m\int_A^B K_s ds$. Če delimo z m, je razlika v potencialih točk B in A v gravitacijskem polju: $U_B - U_A = -\int_A^B K_s ds$.

To zvezo uporabljajo v večini znanstvenih razprav o gravitacijskih modelih in z njo opisujejo prostor z eno samo skalarno funkcijo (glej na primer potencialni model; Kincses in Tóth 2011), medtem ko imajo v zakonu o gravitaciji pomembno vlogo predvsem vektorji, ki označujejo prostor. Glavni razlog za to je, da lažje shajamo z aritmetičnimi operacijami s številkami, kot z računanjem z vektorji. Z drugimi besedami, za delo s potenciali reševanje problema pomeni tudi izogibanje računskim problemom.

Čeprav potencialni modeli pogosto pravilno kažejo usmeritev koncentracije populacije ali BDP-ja in prostorsko strukturo, ne morejo podati informacij o smeri, v katero socialni atributi drugih regij privlačijo določeno regijo in sili s katero jo privlačijo.

Z uporabo vektorjev skušamo nakazati v katere smeri evropske regije (NUTS1, 2 in 3) privlačijo ostale regije v gospodarskem prostoru v primerjavi z njihovo dejansko geografsko pozicijo. S to analizo je možno odkriti središča in prelomnice, ki predstavljajo najpomembnejša območja privlačnosti, in vizualizirati razlike med gravitacijskimi orientacijami regij, ki jih bomo kasneje podrobneje opisali. Najprej si oglejmo metodo.

Pri tradicionalnem gravitacijskem modelu (Stewart 1948) je »populacijska sila« med i in j izražena z D_{ij}, kjer sta W_i in W_j populaciji naselij (regij), d_{ij} je razdalja med i in j, in g je empirična konstanta:

$$D_{ij} = g \cdot \left(\frac{W_i \cdot W_j}{d_{ij}^2}\right) \tag{11}$$

S posplošitvijo zgornje formule dobimo zvezi podani v enačbah (12) in (13):

$$D_{ij} = \left|\vec{D}_{ij}\right| = \frac{W_i \cdot W_j}{d_{ij}^c} \tag{12}$$

$$\vec{D}_{ij} = -\frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot \vec{d}_{ij} \tag{13}$$

kjer sta W_i in W_j upoštevani masi, d_{ij} razdalja med njima in c konstanta, ki označuje spremembo intenzivnosti medteritorialnih relacij kot funkcijo razdalje. S povečanjem moči intezivnost medteritorialnih relacij postaja dovzetnejša za razdaljo, hkrati pa se pomen mas postopno zmanjšuje (glej Dusek 2003).

S to razširitvijo formule lahko opredelimo silo med regijama in tudi njeno smer. V izračunih je vektorje dobro razčleniti na x in y komponente in jih nato ločeno povzemati. Za izračun tega učinka (horizontalnih in vertikalnih komponent sil) lahko potrebne formule izpeljemo iz enačbe (14):

$$D_{ij}^X = \frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (x_i - xj) \tag{14}$$

$$D_{ij}^Y = \frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (y_i - y_j) \tag{15}$$

kjer so x_i, x_j, y_i, y_j centroidi regij i in j.

Če pa izračun delamo za vsako regijo, ki je vključena v analizo, lahko smer in silo učinka na dano teritorialno enoto definiramo z enačbami (16) in (17):

$$D_{ij}^X = -\sum_{j=1}^{n} \frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (x_i - x_j) \tag{16}$$

$$D_{ij}^Y = -\sum_{j=1}^{n} \frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (y_i - y_j) \tag{17}$$

S tema enačbama lahko zaradi sile drugih regij vsaki teritorialni enoti definiramo magnitudo in smer sile. Smer vektorja določenega regijam določa smer privlačnosti drugih regij medtem, ko je magnituda vektorja povezana z magnitude sile. Za prikaz sile transformiramo v sorazmerna gibanja po enačbah (18) in (19):

$$x_i^{\mathrm{mod}} = x_i + \left(D_{ij}^X \cdot \frac{x^{\max}}{x^{\min}} \cdot k \frac{1}{\frac{D_{ij}^{X\max}}{D_{ij}^{X\min}}} \right) \tag{18}$$

$$y_i^{\mathrm{mod}} = y_i + \left(D_{ij}^Y \cdot \frac{y^{\max}}{y^{\min}} \cdot k \frac{1}{\frac{D_{ij}^{Y\max}}{D_{ij}^{Y\min}}} \right) \tag{19}$$

kjer sta X_i mod in Y_i mod koordinati novih točk spremenjenih z gravitacijsko silo, x in y sta koordinati prvotnih točk, njihove ekstremne vrednosti so x_{max}, y_{max}, x_{min}, y_{min}, D_{ij} so sile vzdolž osi in k je konstanta, v tem primeru 0.5. Ta vrednost je dobljena kot rezultat ponovitvene procedure.

Nato je dobro primerjati nove točke z originalnimi. To lahko storimo z vizualizacijo, toda pri tako velikem številu točk rezultati niso obetavni. Bolj obetavne rezultate lahko dobimo z uporabo dvodimenzionalne regresijske analize (glej enačbo za evklidsko verzijo v tabeli 1).

Kjer sta x in y koordinati v neodvisni obliki, a in b znaka koordinat v odvisni obliki, sta a' in b' koordinati neodvisne oblike v odvisni obliki. α_1 se nanaša na obseg horizontalnega premika, α_2 pa vertikalen na premik. β_1 in β_2 uporabimo za določitev merske razlike (Φ) in Θ je kot rotacije. SST je skupna vsota

Preglednica 1: Enačbe dvodimenzionalne evklidske regresije.

1. Regresijska enačba	$\begin{pmatrix} A' \\ B' \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} + \begin{pmatrix} \beta_1 & -\beta_2 \\ \beta_2 & \beta_1 \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \end{pmatrix}$
2. Razlika v lestvici	$\Phi = \sqrt{\beta_1^2 + \beta_2^2}$
3. Rotacija	$\Theta = \tan^{-1}\left(\frac{\beta_2}{\beta_1}\right)$
4. β_1	$\beta_1 = \frac{\sum(a_i - \bar{a}) \cdot (x_i - \bar{x}) + \sum(b_i - \bar{b}) \cdot (y_i - \bar{y})}{\sum(x_i - \bar{x})^2 + \sum(y_i - \bar{y})^2}$
5. β_2	$\beta_2 = \frac{\sum(b_i - \bar{b}) \cdot (x_i - \bar{x}) - \sum(a_i - \bar{a}) \cdot (y_i - \bar{y})}{\sum(x_i - \bar{x})^2 + \sum(y - \bar{y})^2}$
6. Horizontalni premik	$\alpha_1 = \bar{a} - \beta_1 \cdot \bar{x} + \beta_2 \cdot \bar{y}$
7. Vertikalni premik	$\alpha_2 = \bar{b} - \beta_2 \cdot \bar{x} - \beta_1 \cdot \bar{y}$
8. Korelacija temelji na pogojih napake	$\alpha_2 = \bar{b} - \beta_2 \cdot \bar{x} - \beta_1 \cdot \bar{y}$
9. Resolucijska razlika kvadratne vsote	$\sum\left[(a_i - \bar{a})^2 + (b_i - \bar{b})^2\right] = \sum\left[(a_i' - \bar{a})^2 + (b_i' - \bar{b})^2\right] + \sum\left[(a_i - a_i')^2 + (b_i - b_i')^2\right]$ $\mathrm{SST} = \mathrm{SSR} + \mathrm{SSE}$
10. A'	$A' = \alpha_1 + \beta_1(X) - \beta_2(Y)$
11. B'	$B' = \alpha_2 + \beta_2(X) + \beta_1(Y)$

Vir: Dusek 2011, 14, po Toblerju (1994) in Friedman-Kohlerju (2003)

kvadratov, SSR je vsota kvadratov zaradi regresije, SSE je pojasnjena vsota kvadratov napak (ostankov, ki niso pojasnjeni z regresijo).

Za vizualizacijo dvodimenzionalne regresije, je uporaben program Darcy (D'arcy 1917). Mreža, nameščena na koordinatni sistem odvisne oblike in njena interpolirana spremenjena oblika omogočata nadaljnjo posplošitev informacij o regresiji.

Puščice na sliki 13 kažejo smer premika, barva mreže pa se nanaša na naravo izkrivljanja. Tople barve kažejo divergenco, to je premike v nasprotno smer, kar lahko štejemo za najpomembnejše gravitacijske prelomnice. Območja, ki so obarvana z zelenimi odtenki, nakazujejo nasprotno, to je koncentracijo, premike v isto smer (konvergenco), kar lahko štejemo za najpomembnejše gravitacijske centre.

Našo analizo smo izvedli z NUTS1, 2 in 3 nivoji. Primerjava rezultatov z rezultati dvodimenzionalne regresije je prikazana v preglednici 2.

Preglednica 2: Dvodimenzionalna regresija med gravitacijskimi in geografskimi prostori.

raven	r	α1	α2	β1	β2	Φ	Θ	SST	SSR	SSE
NUTS1	0,91	0,19	0,69	0,99	0,00	0,99	0,00	20 430	19 849	582
NUTS2	0,97	0,04	0,15	1,00	0,00	1,00	0,00	54 121	53 484	638
NUTS3	0,99	0,13	–0,04	1,00	0,00	1,00	0,17	139 884	139 847	37

Nižja kot je raven analize, manjši je odklon gravitacijske točke od prvotne strukture. To smo dokazali s korelacijo ter vsoto kvadratov odklonov in njihovih komponent. Zaradi masnih razlik med regijami analiza, izvedena na različnih teritorialnih ravneh prikaže rezultate, ki so različni po naravi, čeprav so si podobni v mnogih pogledih njihove osnovne strukture. Zato smo se odločili za analizo na vseh teritorialnih ravneh, da bi lahko proučili različne ravni prostorske strukture. Naše rezultate smo prikazali in oblikovali naslednja spoznanja.

Slika 13: Smer izkrivljanja gravitacijskega prostora v primerjavi z geografskim prostorom regij evropske unije (NUTS2).
Glej angleški del prispevka.

Analiza, izvedena na ravni NUTS1, obsega le splošne relacije, ki ne zadoščajo za izvedbo poglobljene analize prostorske strukture. Zato smo nadaljevali z ravnijo NUTS2. V tem primeru (slika 13) lahko nedvoumno vidimo regionalne koncentracije. Menimo, da so to jedrna območja. Na podlagi analize, opravljene na ravni NUTS2 lahko v evropskem prostoru najdemo tri, med seboj nekoliko povezane, gravitacijske centre, to so območja, ki privlačijo ostala območja in je gravitacijski premik usmerjen k njim. Ta tri območja so (slika 13):

- območje, ki obsega Baden-Württemberg, zahodni del Avstrije in vzhodni del Švice;
- območje držav Beneluksa in zahodni del severnega Porenja ter Vestfalijo;
- območje, ki obsega večino Anglije.

V glavnem imajo ta jedrna območja učinek na regije obdelanega področja. Ti trije centri vključujejo tudi dve koncentracijski spodbudi. Močnejša in brez dvoma pomembnejša, se razteza od vzhodnega dela Švice preko južne Francije do Madrida, medtem ko se druga, nekoliko šibkejša, prične v tej točki in gre skozi Apeninski polotok.

4 Primerjava uporabljenih metod

Metode, ki smo jih predstavili v tej študiji, uporabljajo iste podatke, vendar dajejo različne rezultate. Metodološka primerjava rezultatov je razmeroma zapletena. Določanje jedrnih regij je najlažje z uporabo gravitacijske analize, če so to območja s konvergentnimi prostorskimi premiki in jih lahko štejemo za glavne gravitacijske centre. Ta območja so na sliki 13 obarvana zeleno. V primeru drsečega povprečja in metode potencialov je zadeva nekoliko težja. V teh primerih so na podlagi naših podatkov kot jedrne obravnavane regije v zgornji četrtini niza podatkov. Vidna primerjava, na podlagi tega je vidna na sliki 14.

Sklenemo lahko, da jedrne regije, ki temeljijo na eni metodi, ne štejejo za jedrne regije na podlagi drugih metod. V primeru drsečega povprečja so to severnoevropske regije, v primeru potencialnih metod izstopa Berlin, medtem ko so v primeru gravitacijskih metod jedrne regije južne Francije in severne Španije. Presečišče treh modelov pa zagotovo potrjuje obliko banane. Kot sklepajo drugi avtorji, ima Evropsko jedrno območje tudi po naši analizi še vedno obliko banane, vendar pa različne analize poudarjajo obstoj večjega števila dohitevajočih se in povezanih regij. Za potrditev naše izjave bi bila potrebna dodatna analiza časovnih vrst, kar je lahko tema druge študije.

Eden od najpomembnejših rezultatov naše raziskave je ta, da je najbolj odločilen element prostorske strukture pozicija prostorske komponente, pridobljena z ločevanjem potenciala, kar izraža temeljne relacije med jedrom in obrobjem. Ostale komponente le malo spremenijo njen učinek, zato je osnovne prostorske relacije možno le malo izboljšati z uporabo razvojnih orodij.

Slika 14: Primerjava rezultatov treh metod.

Glej angleški del prispevka.

5 Zahvala

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6 Literatura

Glej angleški del prispevka.