Modelling the spatial structure of Europe

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Abstract

How can spatial location affect the operation of society, population or economic conditions? What is the role of neighbourhood and distance in social phenomena? In what way can a social organisation limit spatial barriers? How would spatial structures be affected by the attraction and repulsion of territorial units? Does society only use or also design regions? These questions are explored in this study.

This work analyses some important issues, concepts and analysis procedures of the territorial structure of society and social processes of spatiality. It does not contain a comprehensive theory of spatiality and regional science; it is primarily a practical empirical research.

Many theoretical works aim at defining the spatial structure of Europe. This article provides an overview of models describing the spatial structure of Europe. The study describes the economic spatial structure of Europe using bi-dimensional regression analysis, based on the gravity model. The spatial structure of Europe is illustrated with the help of the gravity model and spatial auto-correlation. With these patterns, it is possible to justify the appropriateness of the models based on different methodological backgrounds by comparing them with the results of this paper.

The subject of field theory concepts and methods that can aid regional analyses is examined, and attempts to offer a synthesised knowledge with a wide variety of examples and methods.

Keywords: bi-dimensional regression, Europe, gravity model, spatial autocorrelation, spatial models.

Introduction

Some of the theories, models and descriptions engaged in the socio-economic spatial structure of Europe are static, i.e. they focus on the current status and describing structures. We classify the 'European Backbone' by Brunet (1989), including what later became called 'Blue Banana' or the 'Central European Boomerang' by Gorzelak (2012), into this

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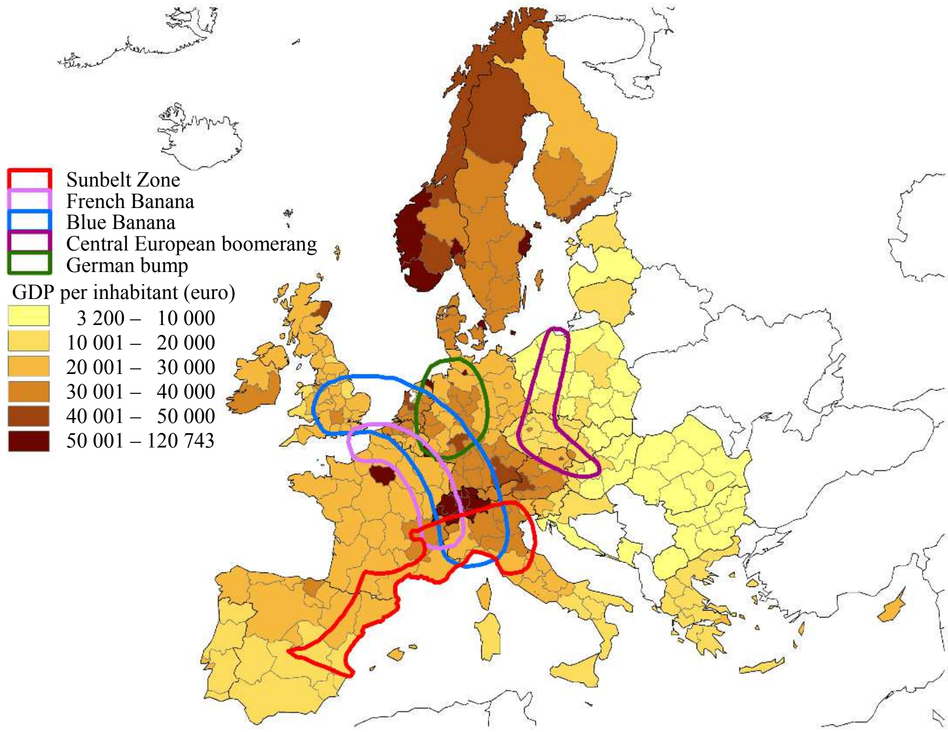
group (Figure 1). Attempts to visualise different polygons (triangles, tetragon) (Brunet 2002) also fall into this category.

Figure 1

Spatial structure models 1



Source: own compilation based on Brunet (1989) and Gorzelak (2012).

Among popular spatial structure models are visualisations that highlight potential movements and changes in spatial structure and development. Some of these are presented, without any claim to completeness. One of them is the developing zone on the northern shore of the Mediterranean Sea, called the European Sunbelt by Kunzmann (1992) (discussed in Kozma 2003) through association with one of the rapidly growing southern zones of the United States of America.

The model of the 'Red Octopus' can be classified as a dynamic model, since it focuses on the future and introduces potential future changes. It is a vision for 2046, showing which of Europe's regions will develop the fastest (Figure 2). In this structure, the body and the Western arms stretch approximately between Birmingham and Barcelona, and toward Rome and Paris. Its form stretches towards Copenhagen–Stockholm–(Helsinki) to the North and Berlin–Poznan–Warsaw and Prague–Vienna–Budapest to the East (van der Meer 1998). Unlike earlier visualisations, this form includes the group of developed zones and their core cities, highlighting the possibilities for decreasing spatial differences by visualising polycentricity and 'eurocorridors' (Szabó 2009). Development is similarly visualised by the 'Blue Star' (Dommergues 1992), with arrows to indicate the directions

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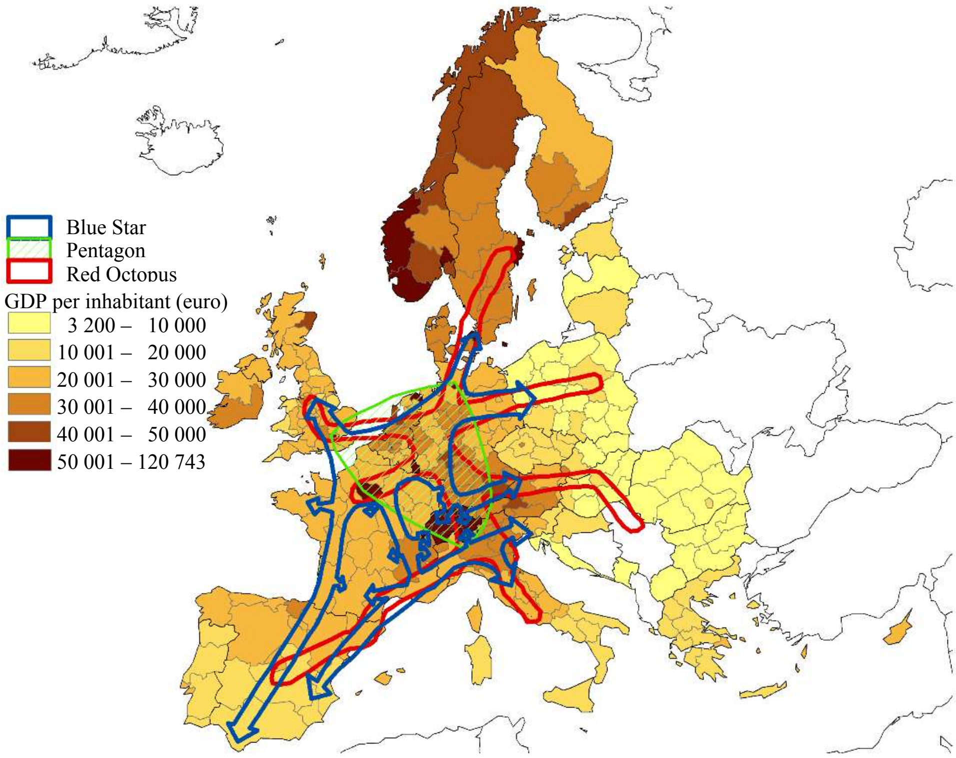
of development and the dynamic areas. Besides the triangle, other polygons are also used to visualise spatial structure, like the quadrangle of London-Amsterdam-Paris-Frankfurt by Lever (1996) or the pentagon that has increased its importance in recent years (Figure 2). The "European Pentagon" is the region defined by London-Paris-Milan-Munich-Hamburg in the European Spatial Development Perspective (ESDP) in 1999.

Figure 2

Spatial structure models 2



Source: own compilation based on van der Meer (1998) and Dommergues (1992).

We argue that the description 'Bunch of Grapes' by Kunzmann & Wegener (1991) and Kunzmann (1992; 1996) includes change and the visualisation of development (Figure 3). By focusing on the polycentric spatial structure, urban development and the dynamic change of urban areas can be highlighted (Szabó 2009). Polycentricity has become an increasingly popular idea, and a key part of the European Spatial Development Perspective (ESDP, agreed at the European Union's Council of Ministers Responsible for Spatial Planning, in Potsdam, 10–11/05/99) (European Commission 1999). It also has an increasing role in the European cohesion policy (Faludi 2005, Kilper 2009). At the same time, however, critical statements appear against this kind of planning approach, for example from the point of view of economic efficiency or sustainable development (Vandermotten et al. 2008).

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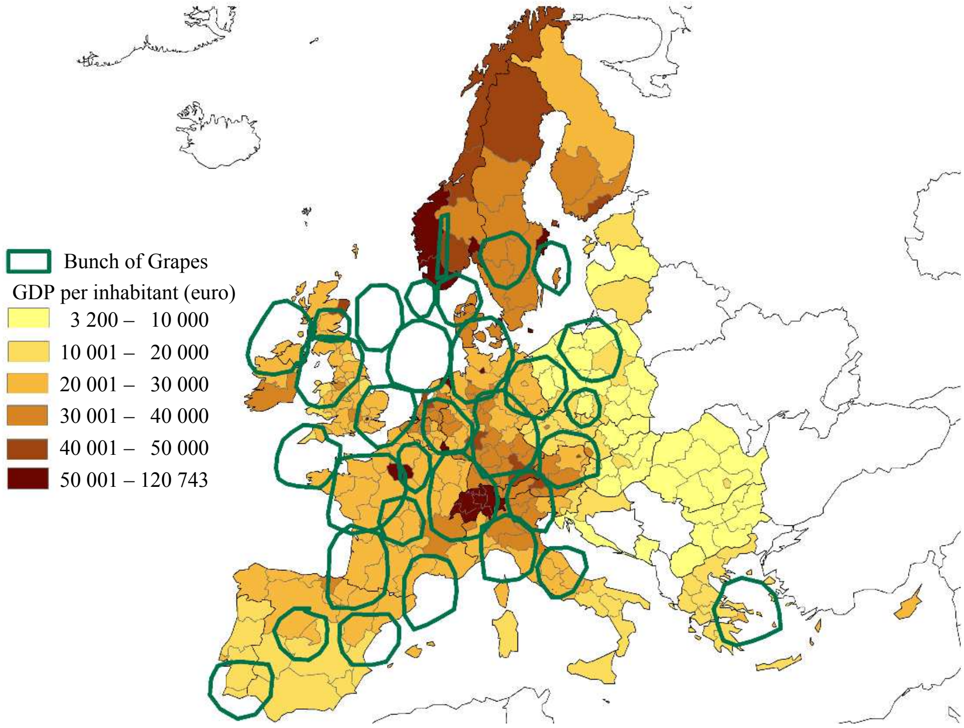
Figure 3

Spatial structure models 3



Source: own compilation based on Kunzmann & Wegener (1991) and Kunzmann (1992, 1996).

In many cases, it is not the form describing the spatial structure or the quality and the extension of the formation – i.e. the static description – that is the crucial question, but rather–the visualisation of the changes, processes and the relationships among regions. Moreover, it is important to analyse the ways and developments that can create the opportunity to utilise advantages and positive effects (Hospers 2003). The paper offers a synthesised knowledge with a broad range of visualisations of examples and methods. Dynamic visualisations can help in this process.

In the following sections, the background of these spatial structural relations and models are examined more thoroughly with the use of the gravity model and bi-dimensional regression. In all of the examples, gross domestic product (GDP) values are applied as a determining measure of territorial development, since the authors believe that its use allows a detailed analysis of spatial structure. GDP is used since this is the most widely used economic variable.

Gravity models and examination of spatial structure

Gravity and potential models that are based on the application of physical forces, are an important approach for examining spatial structure. The use of a gravity analogy in

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examining territorial and spatial structures is not new. This approach, however, does not focus on descriptions by numbers and scalars but the use of vectors. With the approach presented here, attraction directions can be assigned to a given territorial unit that are caused by other units. The universal gravitational law, Newton's gravitational law, states that any two point-like bodies mutually attract each other by a force, the magnitude of which is directly proportional to the product of their mass and is inversely proportional to the square of the distance between them (Budó 1970) (Eq. 1):

$$F = \gamma \cdot \frac{m_1 \cdot m_2}{r^2}, \qquad (1)$$

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

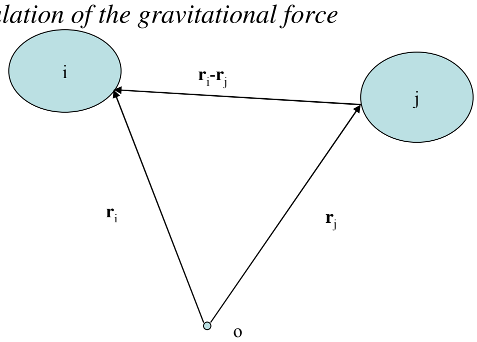
If the radius vector from point mass 2 to point mass 1 is designated by *r*, then the unit vector from point 1 to point 2 is ***—r,*** and therefore the gravitational force applied on point mass 1 due to point mass 2 is (MacDougal 2013):

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

A gravitational force field is confirmed if the direction and the size of gradient K can be defined at each point of the given field. To do so, if K is a vector, three pieces of data are necessary for each point (two in the case of a plane), such as the rectangular components K_x, K_y, K_z of the gradient as the function of the place. However, many force fields , like the gravitational force field, can be described in a much simpler way, that is, using instead of three variables only one scalar function, termed the potential (Figure 4) (Budó 1970).

Figure 4

Calculation of the gravitational force



The force that is applied on i due to j $\quad \vec{F}_{ij} = -\gamma \cdot \frac{m_i \cdot m_j}{r^2} \cdot \frac{\vec{r}_i - \vec{r}_j}{r}$

Source: own compilation.

Potential has a similar relation to gradient as work or potential energy has to force. If in the gravitation field of gradient K, the trial mass on which a force of ***F=mK*** is applied is moved from point A to point B by force ***–F*** (without acceleration) along with some curve,

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then the work of $L = -\int_A^B F_s ds$ has to be done against force ***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:

$$L = E_{potB} - E_{potA} = -\int_A^B F_s ds = -m\int_A^B K_s ds \cdot$$

Dividing by *m*, the potential difference between points B and A in the gravitational space is:

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

By utilising this relationship, in most social scientific applications of the gravitational model, space was intended primarily to be described by only one scalar function (see for example the potential model) (Kincses–Tóth 2012), while in gravitational law, it is mainly the vectors characterising space that have an important role. The main reason for this is that 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 issues.

Even if potential models show, often correctly, 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 attributes of the other regions attract a specified region, or on the force with which they attract it.

Therefore, by using vectors, we are trying to demonstrate in which direction the European regions 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 in respect of the gravitational orientation of the regions.

In the traditional gravitational model (Stewart 1948), the 'population force' between i and j is 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:

$$D_{ij} = g \cdot \left(\frac{W_i \cdot W_j}{d_{ij}^2}\right) \cdot \tag{3}$$

Spatial structure analyses applying potential often present not the gravitation force law but analogous procedures; they define different potential functions.

Of these, we examine those in the form

$$L = \sum_{i,j} g \cdot \left(\frac{W_i \cdot W_j}{d_{ij}^k}\right) \tag{4}$$

k=1, 1.5, 2,..... in more detail. These potentials are transformed using the formula – detailed above – between potential and forces into forces.

With the generalisation of formula (3), the following relationship is given in Eqs. (5) and (6):

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

$$\vec{D}_{ij} = -\frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot \vec{d}_{ij} \qquad (5, 6)$$

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 force, 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 (Wilson 1981, 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 deduced from equations 5 and 6:

$$D_{ij}^X = -\frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (x_i - x_j) \text{ and} \qquad (7)$$

$$D_{ij}^Y = -\frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (y_i - y_j), \qquad (8)$$

where x_i, x_j, y_i, y_j are the coordinates of 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 Eqs. (9) and (10):

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

$$D_{ij}^Y = -\sum_{j=1}^{n} \frac{W_i \cdot W_j}{d_{ij}^{c+1}} \cdot (y_i - y_j) \qquad (9, 10)$$

With these equations, the magnitude and the direction of the force due to the other regions can be defined in each territorial unit. 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 Eqs. (11) and (12):

$$x_i^{\mathrm{mod}} = x_i + \left(D_{ij}^X * \frac{x^{\max}}{x^{\min}} * k \frac{1}{\frac{D_{ij}^{X\max}}{D_{ij}^{X\min}}} \right) \text{ and} \qquad (11)$$

$$y_i^{mod} = y_i + \left(D_{ij}^{Y} * \frac{y^{max}}{y^{min}} * k \frac{1}{\frac{D_{ij}^{Y\,max}}{D_{ij}^{Y\,min}}} \right), \tag{12}$$

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}, x_{min}, and y_{min}, D_{ij} are the forces along the axis and k is a constant, in this case its value is 0.5. This value was obtained as a result of an iteration process.

Linear projection can also be approached in another way, which will be considered as the second method in the following. The direction of the vector assigned to the regions also determines the direction of attraction of the other territorial units, while the length of the vector will be proportionate to the magnitude of the effect of force. In order to make mapping and visualisation possible, the forces obtained are transformed to proportionate movements in the following way (Eqs. (13) and (14)):

$$x_i^{mod} = x_i + \left(D_{ij}^{X} * (x^{max} - x^{min}) * \frac{1}{D_{ij}^{X\,max}} \right) \text{ and} \tag{13}$$

$$y_i^{mod} = x_i + \left(D_{ij}^{y} * (y^{max} - y^{min}) * \frac{1}{D_{ij}^{y\,max}} \right). \tag{14}$$

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}, x_{min} and y_{min}, D_{ij} are the forces along the axes x and y, and their maximums are D_{ij}^{xmax} and D_{ij}^{ymax}.

The simultaneous applicability of the two types of projection attempts to eliminate incidental mode effects, and intends to guarantee common results independent of the projections.

It is worth comparing the point set obtained by the gravitational calculation (using GDP as mass with the baseline point set, that is, with the actual real-world geographic coordinates (and later with each other), and examining how space is changed and distorted by the field of force. In this comparison, not only conventional gravitational fields may be located as shown in other models, but also gravity direction. 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 in the gravitational orientation of regions. In order to realise this in practice, two-dimensional regression needs to be used.

Bi-dimensional regression

It is possible to compare the new point set with the original one by applying this analysis. This comparison can be carried out with visualisation, but in the case of such a large number of points, this is unlikely to provide a promising result by itself. More constructive results can be obtained by applying bidimensional regression analysis (see the equations

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related to the Euclidean version in Table 1), which is a quantifiable method. In this examination, GDP is applied as a weighting variable.

Table 1

Equations of the bidimensional Euclidean regression

1. Regression equation	$\begin{pmatrix} A' \\ B' \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} + \begin{pmatrix} \beta_1 & -\beta_2 \\ \beta_2 & \beta_1 \end{pmatrix} * \begin{pmatrix} X \\ Y \end{pmatrix}$
2. Scale difference	$\Phi = \sqrt{\beta_1^2 + \beta_2^2}$
3. Rotation	$\Theta = \tan^{-1}\left(\frac{\beta_2}{\beta_1}\right)$
4. β1	$\beta_1 = \frac{\sum (a_i - \bar{a})*(x_i - \bar{x}) + \sum (b_i - \bar{b})*(y_i - \bar{y})}{\sum (x_i - \bar{x})^2 + \sum (y_i - \bar{y})^2}$
5. β2	$\beta_2 = \frac{\sum (b_i - \bar{b})*(x_i - \bar{x}) - \sum (a_i - \bar{a})*(y_i - \bar{y})}{\sum (x_i - \bar{x})^2 + \sum (y - \bar{y})^2}$
6. Horizontal shift	$\alpha_1 = \bar{a} - \beta_1 * \bar{x} + \beta_2 * \bar{y}$
7. Vertical shift	$\alpha_2 = \bar{b} - \beta_2 * \bar{x} - \beta_1 * \bar{y}$
8. Correlation based on error terms	$r = \sqrt{1 - \frac{\sum \left[(a_i - a_i)^2 + (b_i - b_i')^2\right]}{\sum \left[(a_i - \bar{a})^2 + (b_i - \bar{b})^2\right]}}$
9. Resolution difference of sum of squares	$\sum \left[(a_i - \bar{a})^2 + (b_i - \bar{b})^2\right] = \sum \left[(a_i' - \bar{a})^2 + (b_i' - \bar{b})^2\right] + \sum \left[(a_i - a_i')^2 + (b_i - b_i')^2\right]$ SST=SSR+SSE
10. A '	$A' = \alpha_1 + \beta_1(X) - \beta_2(Y)$
11. B '	$B' = \alpha_2 + \beta_2(X) + \beta_1(Y)$

Sources: Tobler (1994) and Friedman & Kohler (2003), cited by Dusek (2012 64).

In the equations in Table 1, x and y refer to the coordinates of the independent form, a and b designate the coordinates of the dependent form, and 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 the total sum of squares, SSR is the sum of squares due to regression and SSE is the explained sum of squares of errors/residuals that is not explained by the regression.

To visualise the bidimensional regression, the Darcy program (Vuidel 2009) can be useful. The grid is fitted to the coordinate system of the dependent form, and its modified interpolated position makes it possible to further generalise the information about the points of the regression.

Empirical analysis

The arrows in Figure 5 show the direction of movement, and the grid shading refers to the nature of the distortion. Dark shaded areas refer to concentration and to movements in the same directions (convergence), which can be considered to be the most important gravitational centres.

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Our analysis is carried out at NUTS 2 level. The comparison of the results (between real and modified coordinates) with those of bidimensional regression can be found in Table 2.

Table 2

Bidimensional regression between gravitational and geographical spaces

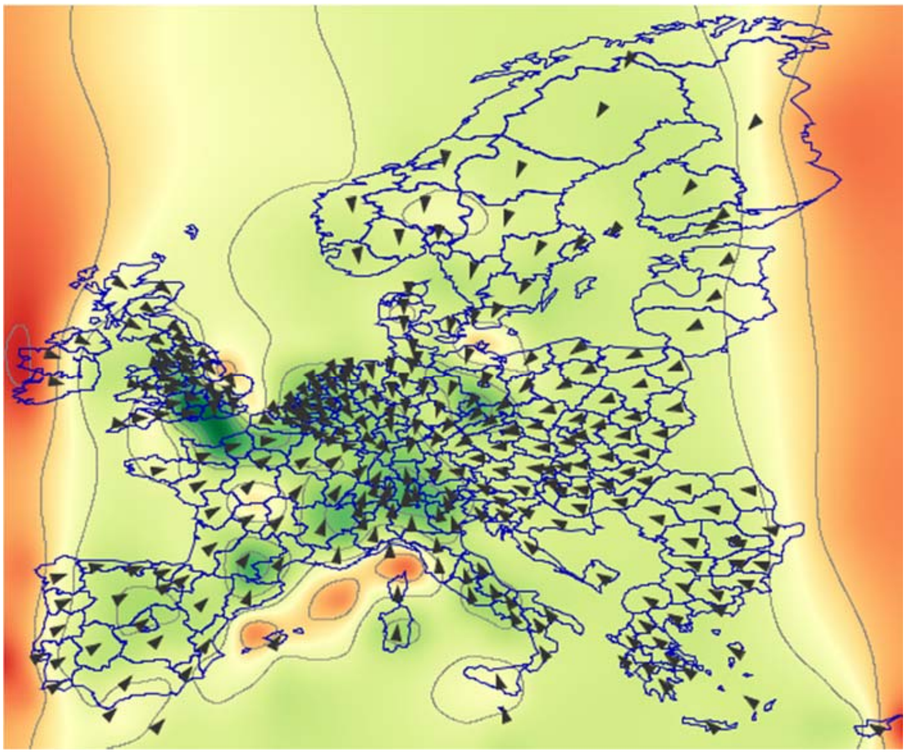
Methods	r	α_1	α_2	β_1	β_2	Φ	Θ	SST	SSR	SSE
1st method	0.96	0.01	0.04	1.00	0.00	1.00	0.00	35,223	34,856	367
2nd method	0.94	0.07	0.30	0.99	0.00	0.99	0.00	55,829	53,141	2,687

Sources: own calculation.

As seen in Table 2, the difference between the two methods is not significant, visualisation results can be considered with certain constraints independent of projections. The relationship between gravitational and geographical coordinates is closer in the case of the first method. The reason for this is that horizontal and vertical shifts as well as scale difference and the angle of rotation is smaller in the case of the first one. Because of these, naturally, the sum of squares of the difference is also substantially lower.

Figure 5

Directions of distortion of gravitational space compared to geographical space for European regions (NUTS 2), 1st method



Sources: own compilation.

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As shown in Fig. 5, regional concentrations can be unambiguously seen, and these are considered to be the core regions. Based on the analysis carried out at NUTS 2 level, five gravitational centres, slightly related to each other, can be found in the European space. Gravitational centres are regions that attract other regions, and the gravitational movement is toward them. These five centres or cores are: 1) the region including Switzerland, Northern Italy and the French regions neighbouring Switzerland; 2) the region including the Benelux countries, Paris and its surroundings and most of the regions in England; 3) the region including Berlin and Brandenburg; 4) the region including Central Italy and 5) the region including Languedoc-Roussillon, Midi-Pyrénées and Catalonia. Primarily, it is these core areas have an effect on the regions in the examined area.

We find that the key element of the economic spatial structure of Europe is the structure reflected by the Blue Banana and the German Hump theory.

Issue of distance

In the presented gravitation models, diverse approaches were applied to distance. This is an accepted practice in social scientific analyses even if it differs somewhat from the original physical analogy, since the square of distance is applied in that, number 2 here means the law, and the value here is not 1.99 or 2.01 but exactly 2. Therefore, the models are not gravitational models but ones based on gravitational analogy, so distance dependences were calculated taking into account other distance exponents in order to examine the roles of masses and distance in modelling the European gravitational space. As found by Tamás Dusek (2003, p. 47) in his work on the gravitational model: "With the increase of the exponent, the intensity of inter-territorial relations becomes more sensitive to distance, in parallel with which the significance of masses gradually declines."

Table 3

Correlation coefficients in case of the two methods, taking into account different exponents

c	1st method	2nd method
0.0	0.752964844	0.693314218
0.5	0.738790230	0.922820959
1.0	0.859542280	0.790773055
1.5	0.860785077	0.725618881
2.0	0.860891879	0.717864602
2.5	0.860918153	0.715549296
3.0	0.860926003	0.714371559

Source: own compilation.

The c values presented here are the c values in formulas 4 and 5, and k=c-1 (and this k is k in the new formula!)

Cases c=0, c=0.5 and c=1 are difficult to reconcile with traditional approaches to space, it can be seen that by increasing c values, the impact area of forces is reduced, which implies the quasi-convergence of correlation coefficients when applying projections.

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Change of spatial structure

The following section attempts to take into account the change of the structure through the gravity calculations for 2000 and 2011. In order to measure changes, the two gravity sets of points are compared and analysed (2000 and 2011). The two-dimensional regression calculations are shown in Tables 4 and 5. Although we are aware of changes in spatial structure taking more than a decade, it was not possible to take into consideration a longer period than this. This is due to the latest change in the NUTS nomenclature, and that data corresponding to the present territorial breakdown is only available for the years between 2000 and 2011.

Table 4

Bidimensional regression between gravitational and geographical spaces

Years	r	α_1	α_2	β_1	β_2	Φ	Θ	SST	SSR	SSE
2000	0.96	0.01	0.03	1.00	0.00	1.00	0.00	35,243	34,876	367
2011	0.96	0.01	0.04	1.00	0.00	1.00	0.00	35,223	34,856	367

Source: own compilation.

Table 5

Bidimensional regression between gravitational spaces

Years	r	α_1	α_2	β_1	β_2	Φ	Θ	SST	SSR	SSE
2011/2000	1.00	0.00	0.01	1.00	0.00	1.00	0.00	35,223	35,223	0

Source: own compilation.

The results show that there is a strong relationship between the two-point systems; the transformed version of the original set of points can be obtained without using rotation ($\Theta = 0$). No essential ratio difference is observed between the two shapes.

As can be seen, there was no marked change in the European spatial structure in the past period. Despite this, it is yet worth examining the spatial picture of the change in the period between 2000 and 2011, since the changes taking shape during this time may form the core elements of the modification of the spatial structure. In terms of the changes from 2000 to 2011, seven gravity centres are shown on the map, indicated by shaded ellipses (Figure 6). They show a crucial part of the economic potential of big cities. Such hubs are the surroundings of Rome, Marseille-Zurich, Madrid, Toulouse, Brussels, Gothenburg, Praha-Chemnitz, etc. Gravity 'breaklines' can be seen in Germany, around Berlin, and in central France.

In general, the change was not fundamental in the examined period but rather focused on only a few areas. These areas are parts of the Bunch of Grapes fields, which may show the increasing importance of this theory. However, there are fewer nodes or 'grapes' than the model predicts.

Regarding the analysis of change, the closest connection is to the Red Octopus model, as most gravity nodes were directly affected by the octopus arms. The analysis confirms the favourable position of certain regions, e.g. the Sunbelt zone and the Blue Banana. The results do not confirm the existence of the Central European Boomerang (Gorzelak 2012), and hence this area is not considered a favourable region at European level.

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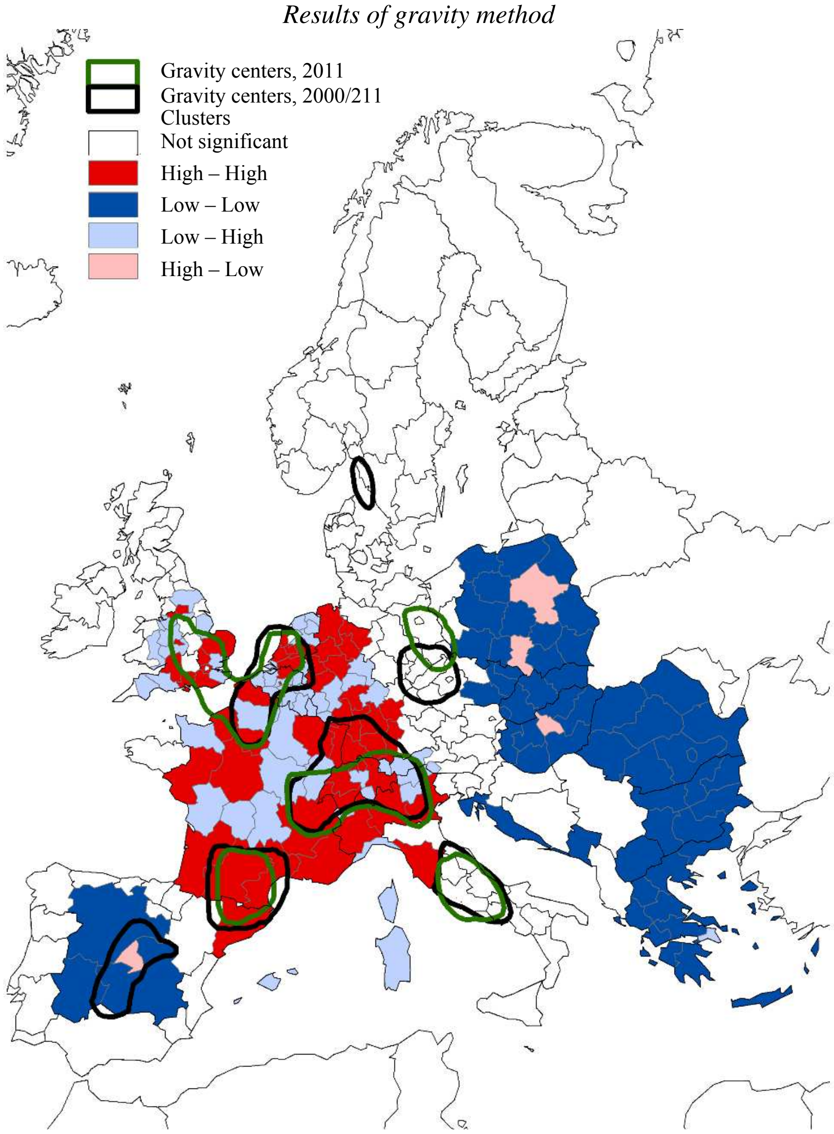
Figure 6

Results of gravity method



Source: own compilation.

The European Commission's NUTS classification is utilised (Nomenclature des unités territoriales statistiques=Nomenclature of Territorial Units for Statistics) on NUTS 2 level (Eurostat 2012). Note is taken that NUTS regions – although defined within minimum and maximum population thresholds at each level – vary considerably in geographical size, with the result that in many cases the use of this system (e.g. in the case of Nordic regions) raises the modifiable area unit problem (Openshaw 1983). This study makes use of the official system, despite its imperfections.

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In order to treat problems and to analyse the results from another aspect, it was also felt necessary to map spatial autocorrelations. Luc Anselin (1995) developed the Local Moran's I statistic, which is one of the most commonly used methods to quantify and visualise spatial autocorrelation; in this article, it is used to explore the spatial economic relations of large cities. Using the designation (1996) of Getis and Ord, I is defined as (Eq. 15):

$$I_i = \frac{(Z_i - \overline{Z})}{S_z^2} * \sum_{j=1}^{N} \left[W_{ij} * (Z_i - \overline{Z}) \right], \qquad (15)$$

where Z is the average of all units, Z_i is the value of unit I, S_z^2 is the dispersion of variable z for all observed units and W_{ij} is the distance weighting factor between units i and j, which comes from the W_{ij} neighbourhood matrix (basically $W_{ij} = 1$ if i and j are neighbours and 0 if they are not). The neighbourhood matrix approach applied in this study examined the straight line distance between the geometrical centres of regions. The smallest threshold distances were used that ensured each region had at least one neighbour. All regions within this are neighbours, while those outside this are not.

If the Local Moran's I value is utilised, the negative values mean a negative autocorrelation and the positive ones a positive autocorrelation. At the same time, the function has a wider range of values than the interval of –1; +1. The indicator also has a standardised version, although currently, this paper is not concerned with this. The Local Moran's statistic is suitable for showing the areas that are similar to or different from their neighbours. The greater the Local Moran's I value, the closer the spatial similarity. However, in case of negative values, it may be concluded that the spatial distribution of the variables is close to a random distribution. Concerning Local Moran's I, the GDP per capita at NUTS 2 level for 2011 was calculated were performed. During the work, the results of the Local Moran's statistic were compared with the initial data in order to examine whether the high degree of similarity is caused by the concentration of the high or low values of the variable (Moran Scatterplots). As a first step, on the horizontal axis of a graph the standardised values of the observation units were plotted, while on the y-axis the corresponding standardised Local Moran's I values (average neighbour values) were plotted. The scatterplot puts the regions into four groups according to their location in the particular quarters of the plane:

1. High–High: area units with a high value, where the neighbourhood also has a high value.
2. High–Low: area units with a high value, where the neighbourhood has a low value.
3. Low–Low: area units with a low value, where the neighbourhood also has a low value.
4. Low–High: area units with a low value, where the neighbourhood has a high value.

The odd-numbered groups show a positive autocorrelation, while the even-numbered groups a negative one.

Of the local spatial autocorrelation indices, it is appropriate to choose a Local Moran's I to search for spatially outlying values. Namely, on the one hand, it shows where the high/low values are grouped in the space (HH–LL) and, on the other hand, it shows where those territorial units are that are significantly different from their neighbours (HL–LH).

Because of the modifiable areal unit problem (Openshaw 1983) it was important when delimiting clusters to consider not only the level of development, i.e. income per capita, but also the population size of the regions where the particular value of GDP per capita could be observed. So with this, it is possible to treat the differences between regions with differing size, and point within the European spatial structure at the most developed zones, which belong to the High–High cluster. The calculations were carried out with GeoDa software, by applying the LISA with EB rates method.

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Our results are identical with those referred to earlier on in many respects, but also differ somewhat from them. Specifically, this model reflects the results of the Sunbelt zone, the Blue Banana and the German hump, with the difference that Île de France as well as Centre, Upper Normandy and Pays de la Loire can all be classified in this among the regions in the best position. These regions are considered central ones only in the European Bunch of Grapes model, though many elements of this model are not supported by the present analysis.

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