XXI. MEZINÁRODNÍ KOLOKVIUM O REGIONÁLNÍCH VĚDÁCH. SBORNÍK PŘÍSPĚVKŮ.

21ST INTERNATIONAL COLLOQUIUM ON REGIONAL SCIENCES. CONFERENCE PROCEEDINGS

Place: Kurdějov (Czech Republic)
June 13-15, 2018

Publisher: Masarykova univerzita, Brno

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Publikace neprošla jazykovou úpravou. / Publication is not a subject of language check.
Za správnost obsahu a originalitu výzkumu zodpovídají autoři. / Authors are fully responsible for the content and originality of the articles.

SPATIAL DATA ANALYSIS AS SELECTED APPROACH TO MEASURING OF THE EU DEVELOPMENT POTENTIAL

Prostorová anlýza jako vybraný přístup k měření rozvojového potenciálu EU

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Annotation

Development potential of the European territory (at the level of country, region or local unit) in the context of the cohesion and competitiveness is frequently discussed in the European Union (EU.) The EU's internal diversity and inequalities are reflected in the quality of living standard, different pace of development of the European territory and also spatial organization of economic and social activities. In this context it is necessary to analyse the possibilities and seek new directions of development that can contribute to increasing the dynamism and development potential of economies. There is no uniform theoretical or quantitative approach to measuring the development and development potential of European territory. The main aim of the paper is to analyse the usability of spatial data analysis as theoretical and quantitative approach to regional development (potential) evaluation in the European Union. Based on the conducted literature review, spatial analysis and particularly method of autocorrelation can be considered as the suitable tool in regional development evaluation that helps to understand the spatial processes in the EU area.

Key words

European Union, development potential, methods, region, spatial data analysis

Anotace

Rozvojový potenciál evropského území (na úrovni země, regionu nebo místní jednotky) je v Evropské unii (EU) často diskutován, a to v kontextu posilování soudržnosti a konkurenceschopnosti. Vnitřní rozmanitost EU a existující rozdíly se odráží v kvalitě života, v rozdílném tempu rozvoje evropského území a také v prostorovém uspořádání hospodářských a sociálních aktivit. V této souvislosti je nutné analyzovat a hledat nové možnosti a směry rozvoje, které mohou přispět ke zvýšení dynamiky rozvojového potenciálu ekonomik. K měření rozvoje a rozvojového potenciálu evropského území neexistuje jednotný teoretický ani kvantitativní přístup. Hlavním cílem příspěvku je analyzovat využitelnost prostorové analýzy dat jako teoretického a kvantitativního přístupu k hodnocení regionálního rozvoje a jeho potenciálu v Evropské unii. Prostorovou analýzu a zejména metodu prostorové autokorelace lze, na základě literární rešerše, považovat za vhodný nástroj pro hodnocení regionálního rozvoje jeho potenciálu, jelikož pomáhá pochopit prostorové procesy. Metoda prostorové autokorelace může být použita pro hodnocení stavu, změny a vývoje prostorové struktury.

Klíčová slova

Evropská unie, rozvojový potenciál, metody, region, prostorová analýza dat

JEL classification: C31, C80, O18, R11, R12

1. Introduction

In recent years, the interest in the issue of territorial imbalances in the European Union (EU) has increased and has been analysed in numerous studies using a variety of different approaches. The reasons can be seen in the fact that economic growth theory has advanced greatly over the last decades-. Also there is the need to reduce the

existing differences in terms of economic, social and territorial development across the various European regions (Ezcurra, Gil, Pascual, 2005). The EU's internal diversity and inequalities are reflected in the quality of living standards, different pace of development of the European territory and also spatial organization of economic and social activities. Assessment of regional (spatial) disparities (mainly at the level of NUTS 2 regions) and identification of key development factors, that may contribute to increasing the dynamics and development potential, is crucial to adopt the measures supporting the long-term growth of regional economies (Poledníková, 2017b). There is no uniform quantitative method for disparities evaluation in the countries and regions in the EU. Several quantitative and qualitative regional indicators (see e.g. Sucháček, 2015) are processed by different mathematical, statistical or econometric methods. Several groups of methods can be identified: univariate statistical methods (e.g. mean, standard deviation, coefficient of variation, correlation, traffic light method); multivariate statistical methods (e.g. cluster analysis, factor analysis); multicriteria decision-making methods; composites indices, see e.g. Klímová, Žítek (2015), Melecký, Skokan (2011), Staníčková (2015), Michálek (2012), Campo, Monteiro, Soares (2008), Ginevičius, Podvezko, Mikelis (2004). In the assessment of the level of socio-economic potential development, it prevails the aim to obtain aggregated (synthetic) index that characterizes the analysed territory in comprehensive way (Cheymetova, Nazmutdinova, 2015). Rivera (2012) compiles *index of regional economic potential* to measure the regional economic strength and model is based on a number of variables of population, work activity, unemployment rate, activity rate, production and income. Miłek, Nowak (2015) employs *Krugman index of dissimilarity* to identify potential regional specialisations. Viturka (2014) evaluates the development potentials of regions based on the synthesis of three components: business environment quality, innovation potential of companies and use of human resources (UHR). Other authors use less or more sophisticated statistical methods and econometrics models, e.g. Petrakos (2001) uses *statistical analysis* as coefficient of regional variation, β-convergence coefficient, the β-density coefficient estimated from the regression of various economic indicators on regional population density. This author also uses *cartographic analysis* that based on maps allows the detection of possible west-east or core-periphery patterns of change, the formation of possible development axes. Kalnina-Lukasevica (2003) introduces the *Synthesized Model* identifying the causation of regional development trends, the priority areas of policy and recommendations and intervention to stimulate economic development (Poledníková, 2017a). Despite the advantages of these methods, their application to spatial data is problematic. Spatial data includes, in addition to attribute information indicating the characteristics of the observed event, spatial information indicating the location of the given even (Spurná, 2008). Although we can find studies including the importance of the spatial aspect of data in measuring socio-economic differentiation, in the vast majority of existing research the non-spatial statistics and indicators still prevail. This is in contradiction with current regional economy that introduces space into economic theories and to practical procedures and trends in quantitative geography emphasing the application of spatial analysis (local and exploratory spatial analysis) (Poledníková, 2017b).

The main aim of the paper is to analyse the usability of spatial data analysis as theoretical and quantitative approach to regional development (potential) evaluation in the EU. To achieve this goal, the method of a literature review is used. The method of literature review objectively describes and discusses the state of the science of a specific topic from theoretical and contextual point of view (Rother, 2007). Literature review has an important role in continuing education because it provides current thinking and research on a selected area of study, and may justify future research into a previously overlooked or understudied area (Rother, 2007; Poledníková, 2017a). The literature review on the specific aspects of spatial data analysis used in the context of evaluation of regional development is the initial phase before the further empirical research work. Literature review considers the European, American also Asian research studies, papers and books. In order to analyse quality academic journal or conference proceedings articles, worldwide renowned citation databases Web of Science, Scopus and EBSCO database were selected. The date of papers' publication was limited for the period 2000–2017. The first part of the paper introduces the theoretical framework of spatial economics. Based on the review of research studies, the second part of the paper presents the usability of spatial data analysis for the regional development (potential) evaluation in the terms of territorial level, used factors/ indicators, methods and main results. Finally, main results of literature review are concluded.

2. Theoretical framework of spatial economics

Mainstream economics has traditionally paid remarkably little attention to the location of economic activity to the choices firms and households make about where to produce and consume, and about how these choices interact. (Fujita, Krugman, J. Venables, 1999) Spatial economics is concerned with the allocation of (scarce) resources over space and the location of economic activity (Duranton, 2008). Spatial economics should include all branches of economics dealing with the analysis of economic processes and developments in geographical space (Fujita, 2010, p. 1). Most fundamental theory of spatial economics is the general theory of location and space-economy using the terminology of Isard (1949), the new economic geography (NEG) initiated by Paul Krugman in the early

1990s represents the newest wave in the development of general location theory. According to Isard "the general theory of location and space-economy is conceived as embracing the total spatial array of economic activities, with attention paid to the geographic distribution of inputs and outputs and the geographic variations in prices and costs." (Fujita, 2010, p. 2). Developing general location models help us to understand important features of spatial economies (at various levels of spatial scale) in a unified manner. Many important features of actual spatial economies were successfully analysed such as: the formation of core-periphery spatial structures and income disparities within a country as well as among a system of nations; the "flying geese" pattern of industrial relocation within a country as well as among countries; the formation of various types of industrial agglomeration and specialized cities; the emergence of a hierarchical urban system in a country; and the formation of various types of specialized zones within cities. The spatial economics have been developed periodically by great location theorists, geographers and economists such as Launhardt (1885), Marshall (1890), Weber (1909), Hotelling (1929), Ohlin (1933), Christaller (1933), Kaldor (1935), Hoover (1936, 1937), Lösch (1940) and Isard (1949). On the other hand, the history of spatial economics is somewhat perplexing. Spatial economics remained at the periphery of economic science until very recently. As suggested by Krugman (1995), this is perhaps due to the lack in the past of a unified framework, or of a comprehensive general location theory. (Fujita, 2010, p. 2). Johann Heinrich von Thünen represents the oldest and the grandest attempt to develop a general location theory. He imagined an "isolated state" where a very large town is located at the centre of a homogeneous plain. He then attempted to determine simultaneously all variables of the economy through competitive markets of goods, labour and land, with a special focus on the land use pattern and land rent pattern in the agricultural hinterland. Later Thünen's model was widen by Alonso in 1964 to understand land use patterns in cities. (Duranton, 2008, p. 4). The next stage of general location theory centred on the development of industrial location theory, mostly by German scholars, was in the late 19th century and the first half of the 20th century. With an explicit consideration of scale economies or indivisibilities in manufacturing production, they had developed industrial location theory together with noncompetitive models of firms. Lösch (1940) developed theory of market areas in which oligopolistic competition among firms producing a homogeneous product under increasing returns leads to the formative of hexagonal market areas. In England, meanwhile, Marshall (1890) presented study on industrial agglomeration, in which he examined systematically the reasons for the concentration of specialized industries in particular localities. According to Marshall, externalities are crucial in the in the formation of economic agglomerations and generate something like a lock-in effect. (Fujita, 2010, p. 9). Following Marshall, local increasing returns could arise because of knowledge spillovers, linkages between input suppliers and final producers, and thick local labour market interactions. (Duranton, 2008, p. 5) Between the early 1940s and the early 60s, the influence of neoclassical economics was so strong that little progress was made in developing new general location models based on noncompetitive theory. On one side, the neoclassical general equilibrium school in the tradition of Walras, Pareto and Hicks maintained that a flexible application of the basic competitive theory can satisfactorily handle the problem of space. On the other side, the other school, led by Isard, asserted that in order to capture the essential impact of space on the distribution of economic activities, new models were needed that were fundamentals different from those found in standard general equilibrium theory based on perfect competition. In the next stage, several successful attempts were made to formulate general location models in the context of urban morphology. Theoretically, these urban models served as precursors to the NEG. (Fujita 2010, p. 4). The spatial economy was given new impetus in the 1990s with the work on the new economic geography, which provided economists with new tools to examine why and where population or economic activity is located. The concentrations of population or economic activity are subject to agglomeration economies and are thus self-reinforcing. The new economic geography seeks to understand why such concentrations arise and why they are self-reinforcing. With this the question is linked: How has spatial concentration evolved with growth and development, and what are the efficiency implications of too much or too little spatial concentration? (Nallari, Griffith, Yusuf, 2012). The central topic of NEG has been how to explain the emergence of a core-periphery structure on a nationwide scale, or on an international scale. The hallmark of the NEG is a general equilibrium approach to the modelling of endogenous agglomeration forces generated through the three-way interactions among increasing returns, transport costs (broadly defined), and the movement of production factors. (Fujita, 2010, p. 2). All early models in the NEG using the modelling framework based on the Dixit–Stiglitz model of monopolistic competition, see Fujita, Krugman, J. Venables (1999); Combes, Mayer Thisse (2008).

3. Review of spatial data analysis used to regional development potential evaluation in the EU

We can distinguish between two spatial effects: spatial dependence and spatial heterogeneity. Intuitively, observations from adjacent regions can on the one hand be correlated (spatial dependence/spatial autocorrelation, measured by Moran's I), or on the other hand a functional relationship can vary across the regions (spatial heterogeneity, measured by Getis-Ord Gi). Spatial autocorrelation can stem from aggregation of variables.

Because the underlying spatial scale of the variable is not correctly reflected within the aggregated variable, the result might be exposed to spatial autocorrelation. Although this kind of measurement error is likely to occur it is not the main source of spatial dependence. Spatial autocorrelation derives to a large extent from the fact that localities interact with each other. The relationship of correlation and distance is in most instances a negative one. Spatial heterogeneity can be dealt with by standard econometric methods. In many cases the assumption of a stable functional relationship across space might not hold. (Feldkircher, 2006)

Following part describes the main findings of analysed literature in terms of the territorial unit, indicators, approaches and methods and also basic results and findings of studies. Main results of literature review are summarized in the table 1 in the Appendix.

The method of spatial autocorrelation is mostly applied at the lower territorial level in the European states. Spatial data includes, in addition to attribute information indicating the characteristics of the observed event, spatial information indicating the location of the given even (Spurná, 2008). Although we can find studies including the importance of the spatial aspect of data in measuring socio-economic differentiation, in the vast majority of existing research the non-spatial statistics and indicators still prevail. This is in contradiction with the current regional economy that introduces space into economic theories and to practical procedures and trends in quantitative geography emphasising the application of spatial analysis (local and exploratory spatial analysis), see e.g. Novák, Netrdová (2011). The theory of spatial autocorrelation has been a key element of geographical analysis for more than twenty years. A number of measurements of spatial autocorrelation were proposed so that we can investigate the spatial process of geographical evolution from differing points of view. Spatial autocorrelation is a property of spatial data that exists whenever there is a systematic pattern in the values recorded at locations in a map. The term of spatial autocorrelation elaborated authors Cliff and Ord in 1973 and as a method of Exploratory Spatial Data Analysis. Spatial autocorrelation is the correlation among values of a single variable strictly attributable to the proximity of those values in geographic space, introducing a deviation from the independent observation assumption of classical statistics.

The spatial data analysis (and the method of spatial autocorrelation) is mostly applied at the lower territorial level in the European states. Spatial autocorrelation is used in case of municipalities in Slovak Republic, Czech Republic by Novák, Netrdová (2011), Slavík, Grác, Klobučník (2011), at the level of NUTS 3 regions in Germany and Central and Eastern Europe by Dańska-Borsiak, Laskowska (2014), Zierahn (2010), Smętkowski, Wójcik (2010), Pautelli, Griffith, Tiefelsdorf, Nijkamp (2006). The sample of the higher territorial level of NUTS 2 and NUTS 3 regions, as well as functional regions, used Laskowska, Borsiak (2016), Brasili, Bruno, Saguatti (2012), Chapman, Meliciani (2012), Ertur, Koch (2006), Feldkircher (2006), Stirboeck (2004), Gezici (2004), Niebuhr (2003), Le Gallo, Ertur (2000), moreover López-Bazo, Vayá, Artís (2004), Verspagen (2007) analysed the NUTS 1, NUTS 2 and also mix these regions. Unbalanced development and disparities among regional economics are an important topic at the international, especially in China, where the exploratory data spatial analysis are used at the county level, by Ma, Pei (2010), at the 31 administrative regions on the provincial level by Min, Chen, (2012), or at the 30 regions on the provincial level by Xie, Liu, Liu, Wang (2014). (Poledníková, 2017b).

The spatial data analysis and the method of spatial autocorrelation involve the wide range of variables. Brasili, Bruno, Saguatti (2012) analysed the economic convergence among European NUTS 2 regions based on GDP per capita, regional employment rate and the percentage of agricultural employment. Novák, Netrdová (2011), Slavík, Grác, Klobučník (2011), Zierahn (2010), Smętkowski, Wójcik (2010) focused on spatial differentiation of social, demographic and economic variables. Spurná (2008), Pautelli, Griffith, Tiefelsdorf, Nijkamp (2006) focused on role unemployment rate. Verspagen (2007) discusses the possibility of a spatial hierarchy of innovation and growth dynamics in Europe where 30 variables of general state of economic development, education and patenting were used. (Poledníková, 2017b). Ertur, Koch (2006) studied the space–time dynamics of regional GDP in the context of the enlargement of the EU. Feldkircher (2006) investigated absolute convergence (by GDP per capita as explanatory variable, yearly average growth rate as the dependent variable) within the EU. Stirboeck (2004) analyses the sectoral specialisation patterns of the 56 NUTS 2 regions in the EU and focused on the regional investment and employment shares in relation to an economy of reference (relative specialisation of gross fixed capital formation and relative specialisation of employment is measured). Niebuhr (2003) analysed the regional data on unemployment, working population, employment, population and area. Chapman, Meliciani (2012) and Le Gallo, Ertur (2000) studied the distribution of regional GDP per capita in selected EU countries as well as López-Bazo, Vayá, Artís (2004) who analyze the influence of externalities on production technology across regional economies, on steady state levels of income, and on the process of growth (gross domestic product per worker and labour productivity are main variables). Gezici (2004) examined the spatial dependence of the level of income and its relationship to regional inequality in terms of GDP per capita in Turkey. Ma, Pei (2010) used the index of the regional per capita gross domestic product (GDP), while Min, Chen (2012) investigate the possible

influential factors of spatial disparities of agricultural mechanization in China. Xie, Liu, Liu, Wang (2014) studied energy consumption and social-economic data (population growth rate, GDP growth rate, urbanization rate, industrialized rate, percentage of industry production value change, percentage of transportation industry production value change).

The method of spatial data analysis has been applied in many different views of territorial development evaluation. For example Laskowska Dańska-Borsiak (2016) used the spatial analysis (Moran's and LISA statistics, the bivariate Moran's statistics-BiLISA) to examine the relationship between human capital and GDP per capita in the European NUTS 2 regions. The results show that most clusters consist of regions with high income per capita that are surrounded by regions with high levels of human capital, but the Balkans also show a very large concentration of regions with low values of both variables. In some EU countries, the NUTS-2 regions with the national capital cities are characterised by a high-low relationship between human capital and spatially lagged GDP per capita. These are the regions of Közép-Magyarország (with Budapest), Praha, Mazowieckie (with Warsaw), Bucuresti-Ilfov, and Área Metropolitana de Lisboa. As expected, region's GDP per capita is positively influenced by its values in the neighbouring regions. According to Brasili, Bruno, Saguatti (2012) the spatial distribution of the regional per capita GDP in 1980 suggests that there was spatial heterogeneity, with two clusters of richer and poorer regions. The hypothesis that the geographical and economic peripheries in Europe substantially coincide is thus supported by this result. Chapman, Meliciani (2012) found that spatial correlation in per capita GDP has not increased over time 1998-2005, thus suggesting that agglomeration forces are not able to explain the increase in within countries disparities. Le Gallo, Ertur's (2000) study of the spatial distribution of regional per capita GDP in Europe over 1980-1995 using exploratory spatial data analysis highlights the importance of spatial interactions and geographical locations in regional growth and convergence issues. Spatial data analysis appears therefore as a powerful tool to finely reveal the characteristics of economic development of each region in relation to those of its geographical environment. Analysis reveals significant positive global spatial autocorrelation, which is persistent over the whole period: regions with relatively high (resp. low) per capita GDP are and remain localized close to other regions with relatively high (low) per capita GDP and that the spatial distribution of regional per capita GDP is not random. The Moran scatterplot and LISA show the persistence of the high-high and low-low clustering types for regional per capita GDP, confirming the north-south polarization of European regions. This reveals some kind of spatial heterogeneity hidden in the global positive spatial autocorrelation pattern and may indicate the co-existence of two distinct spatial regimes. Spatial effects could then perform differently in Northern Europe than in Southern Europe. Ertur, Koch (2006) continue in Le Gallo, Ertur's (2000) study and measure, based on nearest neighbours spatial weight matrix, global and local spatial autocorrelation (Getis–Ord statistics) of European regional GDP per capita in the period 1995–2000. The results also highlighted the new North–West/East polarization pattern which appears with the enlargement process to Central and Eastern European countries and which replaces the previous North–South polarization pattern often underlined in the literature for EU15. They point out that these results have important implications on the way regional and cohesion policies have to be designed because the expected effects of such policies on a given region could be over- or under-estimated depending on the spatial interaction pattern characterizing it. Indeed, spillovers and spatial externalities underlying the spatial autocorrelation are likely to affect regional development processes and therefore should be seriously taken into account. Feldkircher (2006) stated that spatial interactions such as technological spillovers or factor mobility, both being important forces for the process of convergence, should not be neglected. Results showed that growth performance and convergence depend crucially on the development of a region's surrounding. López-Bazo, Vayá, Artís (2004) analyse the influence of externalities on production technology across regional economies, on steady state levels of income, and on the process of growth. The results showed the relevance of interdependencies between regional economies by a simple growth model in which externalities across economies positively influence the process of production. Stirboeck (2004) check the robustness of the recent findings on the economic and locational determinants of regional specialisation patterns for spatial correlation. According him spatial data analysis using of the Getis-Ord statistics there was no strong clusters of sectoral specialisation across regions included in the study. Gezici (2004) looks at the spatial patterns of GDP per capita in order to examine spillover effects in province in Turkey. Ma, Pei (2010) combine exploratory spatial data analysis with GIS technology to investigate the influence of the 2008 Olympics Games for the development of regional economics in Beijing and to explore the possibility that important historical events or national policy guides may associate with change in spatial patterns of regional economic disparities over time. Results show not strong evidences of global spatial autocorrelation, but clear evidences of local spatial autocorrelation and spatial heterogeneity in the distribution of regional per capita GDP. Min, Chen (2012) used exploratory spatial data analysis as a descriptive step before suggesting dynamic factors to explain the spatial patterns and before estimating and testing more sophisticated regression models (Spatial Lag Model and Spatial Error Model). The results showed the spatial distribution of agricultural mechanization in Chinese provinces is significantly uneven. Agricultural mechanization is much higher in the Northern provinces than in the southern provinces of China. Since the spatial autocorrelation seems to affect agricultural mechanization. Xie, Liu, Liu,

Wang (2014) stated that traditional methods measuring the regional disparities ignored the factor of geographical position, which may not truly reflect the spatial characteristics of regional disparities. ESDA mainly measuring spatial association can solve the problem of spatial relationship between regions. Energy consumption changes in China and its driving forces have shown a spatially positive correlation. The residuals of standard regression model also showed positive autocorrelation, indicating that stand multiple linear regression model failed to consider all the spatial dependencies.

Conclusion

Most of studies use the comprehensive quantitative approaches to the assessment of the socio-economic potential of territory applying the statistical method or econometric models. Other important and popular group of used method represents spatial data analysis, especially method of spatial autocorrelation, have been applied to many fields. Detailed analysis of literature sources was focused especially on territorial unit, indicators and results used in the issue of the usability of spatial data analysis for development potential evaluation. Based on the conducted literature review, spatial analysis and particularly method of autocorrelation can be considered as the suitable tool in the analysis of regional economic, social and territorial differentiation and variability, which complements the spatial dimension in the EU area. Spatial autocorrelation can be used as a tool for evaluation of the state, changes and development of the spatial structure.

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Appendix

Table 1: Review of spatial data analysis used to regional development potential evaluation in the EU

Author (Year, Title of paper)	Territorial focus	Indicators	Main results
BRASILI, C., F. BRUNO, SAGUATTI, A (2012). *A spatial econometric approach to EU regional disparities between economic and geographical periphery.*	NUTS 2, NUTS 3 regions	GDP per capita, regional employment rate, the percentage of agricultural employment	The spatial distribution of the regional per capita GDP between 1980 and 2006 suggests that there was spatial heterogeneity, with two clusters of richer and poorer regions. The geographical and economic peripheries in Europe substantially coincide is confirmed. Spatial heterogeneity is also evident with regards to the other variables considered in the model.
CHAPMAN, SA, MELICIANI V., (2012). *Income Disparities in the Enlarged EU: Socio-economic, Specialisation and Geographical Clusters.*	NUTS 2, NUTS 3 regions	regional GDP per capita	Spatial correlation has not increased over time 1998-2005, agglomeration forces are not able to explain the increase in within countries disparities. The structural factors are becoming increasingly important for explaining differences in per capita GDP across regions. The distribution conditioned by neighbours' income is not significantly different from the original one in either year.
DAŃSKA-BORSIAK, B., LASKOWSKA, I. (2014). *Selected Intangible Factors Of Regional Development: An Analysis Of Spatial Relationships.*	NUTS 3 regions	GDP per capita, human and social capital	Spatial clustering of high values (and/or low values) of human and social capital is significant (clustering is stronger for social capital, as the Moran's I-values are higher than for human capital). Social capital showed the tendency for the clustering of positive values. The correlation was positive and is of high–high or low–low type. No significant changes in the spatial patterns occurred in relation to human and social capital. The next analysis confirmed the positive correlation between the GNP level per capita and the human capital measure. However, the results of the spatial analysis show that some subregions with the high level of development are surrounded by regions with low human capital and social capital.
ERTUR, C., KOCH, W., (2006). *Regional disparities in the European Union and the enlargement process: an exploratory spatial data analysis, 1995–2000.*	NUTS 2, NUTS 3 regions	regional GDP per capita	The strong evidence of both spatial autocorrelation highlighted the fact that the per capita GDP level for a given region is not independent of neighboring regions per capita GDP levels in the period 1995-2000. The analysis of average annual growth rates of per capita GDP also showed strong evidence in favor of spatial autocorrelation: the economic dynamism of a given region is highly correlated to the economic dynamism of neighboring regions. New North–West/East polarization pattern appears with the enlargement process which replaces the previous North–South polarization.
EZCURRA, R., C. GIL, PASCUAL, P. (2005). *Regional welfare disparities: the case of the European Union.*	NUTS 1 regions	national component, the spatial location, the productive structure, R&D expenditure	Regional differences in productivity are the main explanatory factor behind observed welfare inequality in the European context. Empirical evidence highlights the importance of variables such as the national component, the spatial location, the productive structure and the percentage of GDP devoted to investment or to R&D expenditure, in explaining the dynamics of the regional welfare distribution in the EU.
FELDKIRCHER, M. (2006). *Regional Convergence within the EU-25: A Spatial Econometric Analysis.*	NUTS 2 regions	GDP per capita (explanatory variable), yearly average growth rate (the dependent variable)	It is shown that growth performance and convergence depend crucially on the development of a region's surrounding. The detected spatial autocorrelation is of substantive form indicating that least squares estimation of the absolute convergence model yields biased results. According to Local Moran's I, Europe is divided into three growth zones: Clusters of fast growing regions in the East and West of Europe and in between a cluster of slow growing regions. Significant growth clusters indicate that regions

Author (Year, Title of paper)	Territorial focus	Indicators	Main results
			located in a dynamic surrounding of high growing localities are more likely to show high growth rates than ones that are neighbors of "slow-growing" areas. This clustering phenomenon can be due to the existence of regional spillovers.
GALLO LE, J., ERTUR, C., (2000). *Exploratory spatial data analysis of the distribution of regional per capita GDP in Europe, 1980–1995.*	NUTS 2, NUTS 3 regions	regional GDP per capita	Spatial distribution of regional per capita GDP highlights the importance of spatial interactions and geographical locations in regional growth and convergence issues. Significant positive global spatial autocorrelation: regions with relatively high (low) per capita GDP are and remain localized close to other regions with relatively high (low) per capita GDP and that the spatial distribution of regional per capita GDP is not random. The persistence of the high-high and low-low clustering types for regional per capita GDP, confirming the north-south polarization of European regions. This reveals some kind of spatial heterogeneity hidden in the global positive spatial autocorrelation pattern and may indicate the co-existence of two distinct spatial regimes. Spatial effects could then perform differently in Northern Europe than in Southern Europe.
LASKOWSKA, I., DAŃSKA-BORSIAK,B., (2016). *The Importance Of Human Capital For The Economic Development Of EU Regions.*	NUTS 2, NUTS 3 regions	GDP per capita, human capital and social capital	Most clusters consist of regions with high income per capita that are surrounded by regions with high levels of human capital, but the Balkans also show a very large concentration of regions with low values of both variables. In some EU countries, the NUTS-2 regions with the national capital cities are characterised by a high-low relationship between human capital and spatially-lagged GDP per capita. These are the regions of Közép-Magyarország (with Budapest), Praha, Mazowieckie (with Warsaw), Bucuresti-Ilfov, and Área Metropolitana de Lisboa. Moreover, influence of human capital on GDP per capita was assessed by two spatial regression models (a spatial autoregressive model and a spatial error model) and basic specifications were used. As expected, region's GDP per capita is positively influenced by its values in the neighbouring regions.
LÓPEZ-BAZO E., VAYÁ, E., ARTÍS,M., (2004). *Regional externalities and growth: evidence from European regions.*	NUTS 1, NUTS 2 regions	GDP per worker, labour productivity, Agriculture, Energy, Share of employment in each sector, Manufacturing, Construction, Market potential, Patents/GDP, Temperature	The results showed the relevance of interdependencies between regional economies by a simple growth model in which externalities across economies positively influence the process of production. Growth andinitial productivity in the set of neighboring regions enhance growth in any region. For instance, trade and patent citations suggest that the strength of interactions decreases with distance. As a consequence, externalities across regions might be behind the features observed, and already reported in the recent literature, in the spatial distribution of production and its growth. Geographical clusters of regions in which the amount of economic activity is well above or below the average could be, among other things, caused by spillovers that cross the usually artificial regional borders.
NIEBUHR, A. (2003). *Spatial Interaction and Regional Unemployment in Europe.*	NUTS 2, NUTS 3 regions	unemployment, working population, employment, population and area	Spatial distance costs as a reason for insufficient equilibrating forces and persistent disparities between regional labour markets in Europe. The correlation analysis indicated a strong positive autocorrelation of both regional unemployment and the change in regional unemployment. Adjacent regions that form clusters of high and low unemployment seem to be a central feature of disparities in Europe. Spatial dependence is not solely the consequence of national differences since a significant auto-correlation also characterises relative unemployment rates. Unemployment clusters are not exclusively national clusters, covering all regions that belong to the same EU member state.
NOVÁK, J., NETRDOVÁ P. (2011). *Prostorové vzorce sociálně-ekonomické diferenciace obcí v České republice.*	municipalities	25 social, demographic, and economic variables	Six types of spatial clusters were found: core regions, Ostrava, Northern Bohemia, Bohemian-Moravian Highlands, non-development areas, other territories.
PAUTELLI, R., D.A. GRIFFITH, M. TIEFELSDORF, NIJKAMP, P. (2006). *The Use Of Spatial Filtering Techniques.*	NUTS 3 regions	unemployment rates, commuting flows	If shown as graphical visualizations, the spatial filters found in our analyses provide hints on the geographical distribution of unemployment trends. It is an example, map can be interpreted as the visualization of a North-South divide. Results also suggest differences between East and West Germany.

Author (Year, Title of paper)	Territorial focus	Indicators	Main results
SLAVÍK, V., GRÁC, R, KLOBUČNÍK, M. (2011). *Priestorová autokorelácia – metóda vymedzovania a klasifikácie regiónov v kontexte sociálno-ekonomickej regionalizácie Slovenskej republiky*	municipalities	economically active population, unemployment rates	The spatial autocorrelation of economically active population as well as the unemployment rate is showed. Four types of regions were defined: areas with a high proportion of the economically active population and low unemployment rate; regions with low economically active population and low unemployment rate; regions with economically active population, but also with high unemployment rate; municipalities with low economically active population and high unemployment rate.
SMĘTKOWSKI, M., WÓJCIK, P, (2010). *Regional Development in Central and Eastern Europe.*	NUTS 3 regions	GDP, economic structure, labour productivity, labour market situation, condition of enterprises, R&D sector, human capital, infrastructure, external attractiveness	There is decreasing spatial correlation relating to the development level of regions for the Central European macroregion. There is a considerable polycentric of the macroregion since the growth centres in individual countries were separated from one another by less-developed areas, which resulted in the lack of statistical significance of Moran's I, suggesting a random distribution of the growth poles. Polarisation processes were visible, manifested by a spatial concentration of the development dynamic, which meant that regions which were surrounded by faster-developing areas would grow faster themselves and, conversely, slow development rate of neighbouring regions, led to the emergence of macroregions with a low dynamic of growth. This could prove that the regional hinterland does have some, rather weak, influence on development processes.
SPURNÁ, P., (2008). *Prostorová autokorelace – všudypřítomný jev při analýze prostorových dat?*	municipalities	on age index, the share of university educated people, unemployment rate and altitude	The empirical examples based on aggregate statistical data at the municipal level highlight the relevance and usefulness of analysis of spatial autocorrelation. The proportion of university educated people shows more pronounced clusters of above average values - "hot spots". The LISA identified the core or concentration centers of the university educated population corresponding to the largest cities and backgrounds. In the case of the age index, there can be talk of the existence of areas with a higher proportion of children's population in border areas. The LISA results for the unemployment rate and altitude illustrate the link between the high number of municipalities showing significant local spatial autocorrelation and the high level of global spatial autocorrelation. In the case of the unemployment rate, the axes between Prague and the towns of České Budějovice, Liberec and Plzeň with low unemployment rates were identified, while problematic areas such as Northern Bohemia.
STIRBOECK, C., (2004). *A Spatial Econometric Analysis of Regional Specialisation Patterns across EU Regions.*	NUTS 2, NUTS 3 regions	regional investment, employment shares (relative specialisation of gross fixed capital formation and relative specialisation of employment	There were no strong clusters of sectoral specialisation across regions. There are some few clusters (e.g. specialisation in Southern Italy), but these are not very striking. Spatial interdependencies between the level of sectoral specialisation of neighbouring regions in the econometric analysis was rarely detected as significant. The spatial clustering of similar specialisation in some rather unfavourable sectors in the peripheral regions is not generally accompanied by significant spatial interdependencies.
VERSPAGEN, B., (2007). *The Spatial Hierarchy of Technological Change and Economic Development in Europe.*	NUTS 1, NUTS 2 regions	30 variables of general state of economic development, education, patenting	The positive correlations (58% of the cases) is calculated, positive spatial correlation is particularly frequent along the row and column of the GDP per capita. GDP per capita correlates strongly with services and in particular business services, employment, and the same patenting sectors as mentioned before. The other strong correlations are mostly negative (the sectoral employment shares variables, the general economic variables, and the education variables). The results point to a hierarchy consisting of four groups: South Europe, East Europe, West and North Europe. In the South and East, such interactions have not yet emerged very frequently. In the South and East, major urban centres exist in which economic growth and innovation flourishes. But these cities do not seem to support a surrounding area with which knowledge interactions are taking place. The metropolis of the South and East remain isolated centres, not yet capable of generating enough spillovers.
ZIERAHN, U., (2010). *The Importance of Spatial Autocorrelation for*	NUTS 3 regions	employment, the number of employees subject	Regional employment growth is characterised by spatial autocorrelation, the development of employment in a region is interrelated with the employment development of nearby

Author (Year, Title of paper)	Territorial focus	Indicators	Main results
Regional Employment Growth in Germany.		to insurance contribution, average monthly wage	regions. This also holds true for major factors of regional employment, such as wages and qualification.
XIE, H., LIU, G., LIU, Q.,WANG. P.,(2014). *Analysis of Spatial Disparities and Driving Factors of Energy Consumption Change in China Based on Spatial Statistics*	administrative regions	population growth rate, GDP growth rate, urbanization rate, industrialized rate, percentage of industry production value change, percentage of transportation industry production value change	They stated that traditional methods measuring the regional disparities ignored the factor of geographical position, which may not truly reflect the spatial characteristics of regional disparities. ESDA mainly measuring spatial association can solve the problem of spatial relationship between regions. Energy consumption changes in China and its driving forces have shown a spatially positive correlation.
MA, X., PEI, T., (2010). *Exploratory spatial analysis of regional economic disparities in Beijing during 2001-2007.*	county level	index of the regional per capita gross domestic product	Results show not strong evidences of global spatial autocorrelation, but clear evidences of local spatial autocorrelation and spatial heterogeneity in the distribution of regional per capita GDP. Since the economic increasing-speeds of Changping and Shijingshan Districts were significantly lower than their some neighbouring regions, a new centre-surrounding polarization scheme was gradually replacing the North-South polarization scheme in Beijing from 2001 to 2007.
MIN, M..,CHEN, J. (2012). *A Spatial Econometrics Analysis On Regional Disparities Of Agricultural Mechanization In China*	administrative regions	rate of agricultural mechanization, rural net income per capita, government financial investment, educated population in agricultural machinery technology, Cultivated Land per capita, rate of agricultural labour transfer	The results showed the spatial distribution of agricultural mechanization in Chinese provinces is significantly uneven. Agricultural mechanization is much higher in the northern provinces than in the southern provinces of China.

Source: own elaboration based on reviewed references, 2017