EUROPEAN FUNDS AND THE DYNAMICS OF ECONOMIC GROWTH AMONG EU REGIONS: A SPATIAL MODELLING APPROACH

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Manuscript received: February 11, 2024
Revised version: April 14, 2024

Kisiała W., Stępiński B., 2024. European funds and the dynamics of economic growth among EU regions: A spatial modelling approach. *Quaestiones Geographicae* 43(2), Bogucki Wydawnictwo Naukowe, Poznań, pp. 67–80. 3 tables.

Abstract: Contemporary development policy concentrates predominantly on reducing noticeable economic differences in a spatial system, and an important role in this respect is played by EU Cohesion Policy. Owing to the considerable scale of financial exposure of Cohesion Policy, the assessment of effectiveness of the implemented measures and their greater reliance on evidence are of major significance. Despite numerous attempts to empirically verify the effects of EU funds spending, the problem remains unresolved, and the results of recent studies lead frequently to ambiguous conclusions.
The article aims to verify the β-convergence process in EU regions in the years 2007–2015 allowing for the impact of the received EU funds and the spatial effects determining economic growth. In the research, use was made of a convergence approach consisting in the regression modelling of per capita GDP growth. Spatial econometrics methods were applied, by adding variables determining spatial interactions that can influence the economic growth rate to the specification of the estimated models.
The estimated econometric models show that in the years 2007–2015 EU funds positively affected economic growth. At the same time, the process of reducing economic disparities between EU regions was observed. Moreover, the existence of spatial effects for a dependent variable was confirmed. The results also show that the value of the EU funds received in the surrounding area generally did not translate into the dynamics of growth in a given location. The research presented is one of the few in which spatial interaction was verified by using weights matrices based on contiguity, distance, flows and affiliation.

Keywords: European funds, economic growth, convergence, spatial regression, regions, European Union

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Introduction

Despite the numerous changes it has undergone over the years, Cohesion Policy still remains one of the most important fields of EU activity (Pinho et al. 2015; Fratesi, Wishlade 2017; Bachtler, Mendez 2020; Herodowicz 2023). For over three decades, about one-third of all EU budget expenditure has been spent to implement its basic, confirmed by treaties, objective that

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https://doi.org/10.14746/quageo-2024-0020
ISSN 2082-2103, eISSN 2081-6383

consists in supporting the harmonious development of the entire Union through "actions leading to the strengthening of its economic, social and territorial cohesion" (Article 174 of the Treaty on the Functioning of the European Union). When considering a multi-year financial perspective embracing 2014–2020, it corresponded to the amount of ca. 350 bln EUR. A similar sum (excluding the means of the Just Transition Fund) has been planned for the 2021–2027 Cohesion Policy (Regulation 2021/1060 of the European Parliament and of the EU Council of 24 June 2021).

Most of the activities within Cohesion Policy are focused on reducing development disparities between regions and limiting backwardness of the least-favoured regions. Thus, by design, Cohesion Policy should contribute to achieving economic convergence (Kisiała, Suszyńska 2017; Crucitti et al. 2023). What is indicated at the same time is a pro-development character of Cohesion Policy, emphasising an enormous role of its instruments as sources of investment funding, especially in the eastern part of the European Union (Dyba et al. 2018). About 14% of all the government sector investments throughout the entire European Union in the years 2014–2020 are estimated to be co-financed by EU funds, while the share of these investments in countries with a lower socio-economic development level was slightly more than 50% (European Commission, 2022).

The current economic and geopolitical context does not seem to encourage the continuation of the Cohesion Policy in its present form. The majority of the EU economies were seriously and lastingly affected by the results of the financial crisis that started in 2007 and which was followed by a slow return to 'old' development trajectories. From an economic point of view, the COVID-19 pandemic turned out to be even worse; as a result, the overall EU economy saw a decline in the real GDP value by about 6% (European Commission, 2022). When considering the process of leaving the European Union by the United Kingdom—a net contributor to the EU budget—which eventually took place in 2020, one can obtain a picture of increasingly shrinking financial resources which, potentially, could be allocated to Cohesion Policy (Berkowitz et al. 2020; Crescenzi et al. 2020). Hence, even among the highest representatives of the European Commission (Jean-Claude Juncker), during the debate on the 2021–2027 financial perspective, there were calls to "drop some pan-European policies" and limit the scope of activities "to do less more efficiently" (Crescenzi, Giua 2020: 11).

In these circumstances, the question of assessing the effectiveness of the actions carried out and making them even more evidence-based have become of great importance for the future implementation of all EU policies. For Cohesion Policy, it comes down to finding answers to two basic questions: (1) whether the implementation of this policy supports economic growth in the European Union and (2) whether financial means allocated under this policy contribute to reducing development disparities between EU regions and states (thus, whether they support the occurrence of convergence).

Despite numerous attempts to verify empirically the issues mentioned, the problem remains unresolved. The results of more and more recent studies often lead to ambiguous conclusions, and answers to the questions above seem to be far from consensus in the light of the literature. Dall'erba and Fang (2017) point to four groups of work that differ in a stance towards the question of the influence of Cohesion Policy on economic growth:

1. analyses confirming a positive impact of EU funds on economic growth in regions (e.g. Cappelen et al. 2003; Esposti, Bussoletti 2008; Mohl, Hagen 2010; Maynou et al. 2016; Fiaschi et al. 2018), pointing to the need to continue Cohesion Policy;
2. analyses indicating conditional effectiveness of Cohesion Policy, depending on the existence of some factors, e.g. a certain quality of institutions (e.g. Ederveen et al. 2006; Rodríguez-Pose, Garcilazo 2015), or limiting the effectiveness to a specific category of expenditure, e.g. on education and human resources (Rodríguez-Pose, Fratesi 2004);
3. analyses that do not confirm the impact of European funds on economic growth (e.g. Dall'erba, Le Gallo 2008; Antunes et al. 2020), where neither positive nor negative correlation between the amount of the European funds allocated and indicators of economic growth has been found;
4. analyses pointing to a negative impact of the implementation of Cohesion Policy on the

dynamics of economic growth (e.g. Boldrin, Canova 2001; Breidenbach et al. 2019).

It is worth noting that a scientific debate on the effectiveness of the implementation of Cohesion Policy rests for the most part on the research results which do not embrace the spatial extent of the countries entering the EU in 2004 and later, which lowers the value of the assessments and conclusions drawn. This article makes an attempt to fill this gap, providing more arguments concerning the discussion that has been going on in the literature for years.

The aim of the work is to verify the effectiveness of Cohesion Policy implementation in the regions of the EU member states. This objective will be achieved by finding answers to the following questions:

1. Did European funds have an impact on the dynamics of economic growth in the regions of the EU member states and to what extent?
2. Was the implementation of Cohesion Policy accompanied by the process of interregional economic β-convergence?
3. Did the spatial interactions between regions occur? If so, what was the mechanism of the impact on the economic growth rate?

The answers to the questions thus posed were searched by the verification of an econometric model. The spatial scope of the study covers NUTS-2 regions of 27 EU countries (including the United Kingdom, without Croatia; in total 261 territorial units[1]). The temporal scope of the analyses, in view of the best data comparability, covers the years 2007–2015 (concerns the European funds allocated in the 2007–2013 financial perspective).

The paper is organised as follows. The second part presents a review of the most important research results on the impact of European funds on the dynamics of economic growth. The third section contains the characteristics of the econometric model applied and a description of the data. The fourth part shows the results of the model estimation. The work ends with a discussion and conclusions.

Literature review

Owing to the significant financial investment in Cohesion Policy, its operation is subject to comprehensive evaluations by EU institutions. These assessments are based primarily on the results of well-established macroeconomic models such as HERMIN, QUEST and RHOMOLO. They can be found in the cohesion reports published by the European Commission. The latest report (European Commission, 2022) confirms a positive impact of Cohesion Policy funds on the short-term economic growth of the entire European Union, with an increase of approximately 0.4% GDP per year. It indicates that the economic effects of the funds are not distributed equally throughout the EU, but rather concentrate in the regions of member states with the lowest socio-economic development level. The report emphasises the long-term effects of Cohesion Policy, which can last up to 30 years after an investment is implemented. These effects are primarily related to supply, resulting from improvements in the productivity of economic entities and permanent reductions in transport costs.

The assessments presented above are generally consistent with the decisions made and presented in the previous reports by the European Commission (2014, 2017, 2022). The only differences are related to the size of the effects produced in the individual financial perspectives analysed in a given report. These differences, however, are not significant.

The assessment of the effectiveness of Cohesion Policy resulting from the debate among academics seems to be ambiguous. The discrepancies in this respect may stem from different temporal, spatial or subject-matter scopes adopted in individual studies, and also, from different data analysis methods used to assess the impact of Cohesion Policy on the dynamics of economic growth. When organising the main threads of the scientific debate on the effectiveness of Cohesion Policy according to the adopted methods of analysis, Berkowitz et al. (2020) distinguish two groups of research. The first of the mentioned groups, far more numerous and constituting the

[1] Owing to the fact that variables determining spatial interactions have been introduced to the model, regions located outside the European continent were excluded from the analysis. Those were two Portugal regions (Madeira and the Azores), three Spanish regions (Ceuta, Melilla, and the Canary Islands) and four French regions (Guadeloupe, Martinique, French Guiana, and Réunion).

background of the discussion for the conducted analysis, uses regression models based in their primary form on a neoclassical theory of growth. The second group, on the other hand, comprises research applying various statistical techniques (e.g. regression discontinuity design, propensity score matching or a generalised propensity score) based on a quasi-experimental approach. This means that a certain group of regions (or other units) covered by financial support (intervention, public policy) is compared in terms of the adopted measure with an appropriately selected control group that is not subject to such support or intervention. In contrast to a typical experimental scheme, the selection of units to any of the groups is not random (Wójcik 2018).

The significant majority of research on the effectiveness of Cohesion Policy included in the group of regression models is based on the equations constituting the adaptation of two models: (1) the Barro and Sala-i-Martin β-convergence model (Barro, Sala-i-Martin 1992), in which the authors attempted to capture the relationship between income growth in a specific time (dependent variable) and the income level at the initial stage (independent variable) and (2) the Mankiw, Romer and Weil model (Mankiw et al. 1992) characterising the level of income in the economy (dependent variable) as the result of the amount of available capital, labour resources and technological progress (independent variables). With the development of research on the impact of European funds on economic growth, there appeared a series of other variables characterising, e.g. the quality of institutions at national and regional levels, the degree of public authority decentralisation, a social capital level, etc. (Breidenbach et al. 2019; Berkowitz et al. 2020). Besides, the theoretical output of New Economic Geography (Krugman 1991) has become an inspiration to analyse spatial interaction, which makes it possible to determine the influence of European funds allocated in a given region on the dynamics of economic growth in the neighbouring regions (Mohl, Hagen 2010).

The very diversity related to the applied sets of variables in combination with differences in the specification of regression models and the previously mentioned disparities in the adopted temporal, spatial and subject-matter scope of the analyses seem to decide about the lack of compatibility as to the assessment of the influence of European funds on economic growth in the regions of the EU member states. The studies providing positive assessments of Cohesion Policy implementation make up a relatively numerous group. This can be illustrated by the spatial econometric analysis of Fiaschi et al. (2018) with the use of spatial Durbin models (SDMs), in which the authors examined an impact of EU funds on productivity growth (measured by GDP per employee) in the regions of EU-12 states in 1991–2008 (separately for three periods of programming: 1989–1993, 1994–1999 and 2000–2006). What has been confirmed was a positive influence of the expenditure of structural funds on productivity (GDP per worker growth by 1.4% on average) with a simultaneous decrease in regional disparities measured by the Gini index (by 8 p.p.). Moreover, the authors pointed to a greater efficiency of the impact of funds in the last of the investigated programming periods (2000–2006) compared to the previous two (1989–1993 and 1994–1999), which would be indicative of a positive trend in the reforms conducted at the end of the 1990s (the so-called Agenda 2000). The occurrence of positive spatial effects of the investments made (spatial spillovers) has also been stated.

Maynou et al. (2016), who carried out a panel analysis of the impact of EU funds on economic growth in the Eurozone states within NUTS-2 regions in the years 1990–2010, drew similar conclusions in their research. The analysis proves a growth-stimulating impact of EU funds with a simultaneous occurrence of β-convergence. In this case, however, the authors have not confirmed the existence of spatial effects, that is an economic impact of the projects implemented in a given area on development processes in the neighbouring regions.

The positive assessments of the efficiency of Cohesion Policy also result from the research conducted by Mohl and Hagen (2010), whose conclusions are analogous to those drawn by Fiaschi et al. (2018), but based on spatial panel models and referring to the EU-15 Objective 1 regions (the poorest) in the years 1994–2006. Similarly, Esposti and Bussoletti (2008), who used panel analysis, confirmed a positive, albeit poor and spatially diversified, impact of funds on economic growth in those regions in 1989–1999.

On the other hand, while analysing the financial support lent as part of European regional policy in the years 1980–1997, Cappelen et al. (2003) unequivocally confirmed its impact on the dynamics of economic growth and convergence (spatial effects were not studied). Bähr (2008) arrived at similar conclusions in his analysis embracing 1975–1995 (the analysis was conducted by countries). In the context of positive assessments, what is also worth citing is the latest research by Vukašina et al. (2022) proving the existence of a statistically significant, albeit little, impact of European funds on the dynamics of economic growth in the years 2008–2016 in the NUTS-2 regions of the 12 countries which entered the EU in 2004 and 2007 (panel data models).

Somewhat less optimistic conclusions are presented in the group of research indicating conditional effectiveness of Cohesion Policy. This research confirms the influence of Cohesion Policy on economic growth, pointing out at the same time that this influence can be limited to a certain category of expenditure or specific timeframes. This can be illustrated by Rodríguez-Pose and Novak's (2013) panel analysis. The authors point to the effects of Cohesion Policy that differ from one another in particular periods under analysis (1994–1999 and 2000–2006). It has been found that for 1994–1999, European funds had no impact on economic growth in the regions covered by the study (a statistically insignificant variable) while observing the β-convergence process between the regions. A different situation was recorded for the second period assessed (2000–2006). In this case, what was observed was a statistically significant positive impact of financial investments from structural funds on economic growth of the regions under study while maintaining interregional β-convergence. The authors attribute the changes in the observed trends to the process of institutional learning and reforms of EU regional policy adopted after the completion of the 1994–1999 programming period (improvement in the monitoring of the means spent, an increase in capacity of local and regional authorities, etc.). Puigcerver-Peñalver (2007) also paid attention to the differences between the two programming periods stating a positive impact of EU regional policy on economic growth between 1989 and 1993 and the lack of such influence in 1994–1999.

On the other hand, Rodríguez-Pose and Fratesi's (2004) analysis that relies on cross-sectional data from 1989 to 1999 for the Objective 1 regions points to a pro-development character of only some categories of expenditure, namely investment in education and human resources. The authors' contention is that the remaining trends in spending European funds, e.g. on infrastructure and environmental protection, or direct support for entrepreneurship and tourism, did not positively translate into an increase in the economic growth rate in the area under study.

The third group of the analyses points to the ineffectiveness of the intervention made as part of Cohesion Policy, thereby confirming neither a positive nor negative relationship between the amount of the European means spent and the indices of economic growth. Such a conclusion results, among others, from the research of Antunes et al. (2020), who conducted the SDMs analysis for 96 EU-15 regions in 1995–2009. In the research, the existence of interregional β-convergence was proved. However, the model did not confirm the impact of European funds on the dynamics of economic growth in the studied sample (the variable turned out to be statistically insignificant). In addition, the occurrence of spatial effects for all independent variables was found, except for the variable characterising the amount of the fund expenditure. While interpreting the obtained results, the authors point to the need for the coordination of EU funds spending with other policies and investments not coming from public means in order to fully achieve the synergy effect. Dall'erba and Le Gallo (2008) obtained the approximate results in their analysis for 1989–1999 (145 regions of EU-12, spatial lag models).

The most pessimistic conclusions regarding the future of Cohesion Policy result from research pointing to a negative influence of EU funds spending on the dynamics of economic growth. Breidenbach et al. (2019) conducted a spatial econometric analysis using both spatial lag and Durbin models for 127 NUTS-2 regions of EU-15 between 1997 and 2008. The results showed that the structural and investment funds spent had a negative impact on economic growth in the analysed regions. The impact value varied from 0% to −0.5% of GDP in different variants of the described models. A direct negative economic effect was additionally strengthened by negative spatial effects (greater support from EU funds in the neighbouring regions was accompanied by a decrease in per capita GDP growth in a given region). The authors link the obtained results to the issue of disturbances to natural market mechanisms caused by the support implemented within Cohesion Policy. In their work, Boldrin and Canova (2001) formulated similar conclusions based on analyses of the European regional policy in the 1980s and '90s.

In the case of the second analytical trend referring to the effectiveness of Cohesion Policy implementation, that is studies using a quasi-experimental approach, there is a significantly greater compatibility regarding the obtained results. The vast majority of analyses indicate a positive and statistically significant impact of European funds spending on economic growth. The differences relate only to the size of the identified impact effects on the GDP dynamics. Therefore, Becker et al. (2018) estimate the magnitude of this impact in the years 1989–2013 between 0.08% and 0.3% of GDP yearly. Pellegrini et al. (2013) for the period of 1995–2006 indicate an effect amounting to about 0.6–0.9% of GDP yearly, whereas Blouri and von Ehrlich (2020) for the 2007–2013 programming period – on average about 2% of GDP per year.

With regard to the research included in this approach, certain limitations are worth mentioning. These analyses, owing to the specificity of the methods themselves, take *de facto* into account the effectiveness of Cohesion Policy only in the regions with the poorest development level, which have been included in Objective 1 of Cohesion Policy. What is more, as Fratesi (2016) points out, in the case of a quasi-experimental approach, it is difficult to capture an 'isolated' effect of intervention within Cohesion Policy, which may lead to the overestimation of the impact strength. Thus, the application of theory-based regression methods seems to better reflect the mechanisms of the policy influence on economic growth.

Research methods and data

In order to explain whether EU funds determine the dynamics of economic growth in the EU regions, the convergence approach is used. In the classic version, popularised in the works of Barro and Sala-i-Martin (1992, 2004), it consists in the study of the correlation between a relative growth in per capita income and its initial level. In the situation in which initially poorer regions observe a higher growth rate in relation to richer ones, regional inequalities decline, which is called β-convergence. The verification of β-convergence is obtained by way of econometric modelling. In the estimated models, except for the initial state of a variable quantifying the income, some control variables may be taken into consideration as additional factors determining the growth. This is the so-called conditional convergence (Mankiw et al. 1992; Boldrin, Canova 2001).

The starting point for statistical analyses in this research was a single-equation regression model in the form of:

$$\ln\left(\frac{y_{i,\,t_0+T}}{y_{i,\,t_0}}\right) = \alpha + \beta\ln(y_{i,\,t_0}) + \sum_{m=1}^{k}\gamma_m x_{m,\,i} + \varepsilon_i \quad (1)$$

where:
- $y_{i,\,t_0}$ is the level of a regional per capita income in the initial stage (GDP per capita in the *i*-th EU region in 2007),
- $y_{i,\,t_0+T}$ is the level of a regional per capita income in the final stage (2015),
- $x_{m,\,i}$ are exogenous structural variables that may affect per capita income growth,
- α, β, γ_m are estimated structural parameters of the model,
- ε_i is a random component.

Among the tested factors determining economic growth, what is considered in the study is the value of acquired EU funds per capita in a region (EU_FUNDS). This amount relates to all EU funds (including the Cohesion Fund) actually spent in the 2007–2013 financial perspective. The values of the variable for individual regions were established on the basis of the European Commission data available on the Cohesion Open Data Platform[2].

Control variables are also introduced to this model, specifying individual features of the investigated regions. Since there is no consensus in the literature on the set of factors applied in

[2] The European Commission's Cohesion Policy databases are available on the website: https://cohesiondata.ec.europa.eu/browse?limitTo=datasets.

conditional β-convergence analyses, our choice of control variables referred to traditional factors of economic growth, which are investments (physical capital), labour resources (human capital) and technological progress (innovativeness) (Solow 1956). Thus, in modelling, we included growth rates:

– gross fixed capital formation per capita (INVEST), shows the amount of new value added in an economy that is invested rather than consumed. It measures the value of acquisitions of new or existing fixed assets by the business sector, governments and households (excluding their unincorporated enterprises) minus disposals of fixed assets (e.g. Maynou et al. 2016; Scotti et al. 2022);
– proportion of the working age population in a region (LABOUR) is defined as those aged 15–64 in relation to total population size. It estimates an economy's active workforce (e.g. Pinho et al. 2015; Fiaschi et al. 2018);
– number of the employed in the science and technology per 1,000 inhabitants (INNOV) is one of the human resources in science and technology (HRST) indicators collected by the European Commission. HRST are an important national resource as they contribute to the strength of national innovation and potential development in the field of science and technology. Therefore, this indicator can be used as a symptomatic variable to measure the level of innovation and technological progress (e.g. Alecke et al. 2013; Breidenbach et al. 2019).

The data were acquired from Eurostat and transformed into a logarithmic form.

Additionally, we verify whether the studied process was determined by the location. To this end, the traditional β-convergence equation has been modified by adding to the specifications of the estimated models variables defining spatial interactions, which can affect the economic growth rate (marked with the prefix LAG). In spatial econometric analysis, two independent research investigation strategies have been applied, referring to two general modelling procedures: specific to general modelling and general to specific modelling (Florax et al. 2003).

The first strategy draws on the so-called classical approach (Anselin, Rey 1991), in the first stage of which the basic model of the ordinary least square (OLS) method is estimated, according to Eq. (1). Consequently, this model is tested with the use of estimation residuals, i.a. in terms of spatial autocorrelation. The hypothesis on the existence of spatial autocorrelation is verified by global Moran's statistics expressed in the equation:

$$I = \frac{\mathrm{e}^{T}\mathrm{We}}{\mathrm{e}^{T}\mathrm{e}} \quad (2)$$

where e is a vector of residuals, and W is a row-standardised matrix of spatial weights of n degree. When a statistically significant spatial autocorrelation of a random component was recognised, Lagrange Multiplier tests were applied (basic – LM and robust – RLM), making it possible to select a spatial model form: a spatial autoregressive model (SAR) or a spatial error model (SEM). The SAR model verifies an impact of the values of dependent variable from other locations (variable LAG_LN_Y) on the value of this variable in a given location. By contrast, in SEMs, it is presumed that the dependencies identified result from the existence of spatially autocorrelated variables not included in the model or from the measurement errors (Suchecki 2010; Ward, Gleditsch 2019). As a consequence, what is needed is the correction of an original random component with spatial autocorrelation to obtain an independent error term. Spatial models are estimated by the maximum likelihood method (Suchecki, Olejnik 2010).

The second strategy assumes that except for standard components in the β-convergence model, spatial components are additionally introduced in the form of spatial lags of the explained variable (LAG_LN_Y) and explanatory variables (LAG_LN_GDPpc07, LAG_LN_EU_FUNDS, LAG_LN_INVEST, LAG_LN_LABOR, LAG_LN_INNOV) on the right side of the equation. This kind of specification in the literature is called the SDM (LeSage, Fischer 2008). It connects the SAR model with the spatial cross-regressive model, which means that except for a spatially lagged explained variable (economic growth rate), it takes account of both spatially non-lagged and spatially lagged explanatory variables. This makes it possible to verify an impact on the growth rate of exogenous variables acting locally and the so-called spillover effects from other locations (e.g. whether the funds acquired in a given region translate into only this region's development, or whether there are mechanisms of diffusion of development impulses across the surrounding areas).

The estimated SDMs are verified not only with regard to statistical significance of individual variables, but also to the strength of influence of corresponding local and external variables. The situation in which the impact of a given variable from neighbouring locations is stronger than the impact of this variable in the local context is recognised as a sign of the factually erroneous specification of the model (Anselin 2003).

To verify spatial autocorrelation and estimate spatial models, the structure of links between EU regions had to be determined as part of spatial weights matrices. In the research we use four types of spatial weights matrices. Each of them quantifies spatial links in a different way, thus making it possible to verify the mechanism of spatial interaction, determining the economic convergence process at regional level in the European Union. They include:

1. Contiguity matrix W1 – in this case, neighbourhood is defined by the criterion of a common border (contiguity of regions). It is assumed that neighbours are regions which share a common border, regardless of its length (first-order contiguity matrix of a queen type).
2. Distance matrix W2 – the specification of elements of this matrix is based on the distance measurement between the *i*th and *j*th regions. The measurement was carried out in the Euclidean metric and weights were calculated as $w_{ij} = d_{ij}^{-1}$ (inverse distance matrix).
3. Flow matrix W3 – weights reflect real links between the investigated regions in terms of freight movement (total freight flow between load and unload regions in thousand tons)[3]. In accordance with this matrix, neighbouring units are those between which goods were exchanged, and individual weights w_{ij} are equal to the volume of freight from the *i*th region to the *j*th region and vice versa.
4. Block weight matrix W4 – neighbourhood is not understood as geographical vicinity but as an affiliation with the same group. It is assumed that the neighbours of the *i*th region are the remaining regions situated in the same country (EU member state).

Matrix W1 made it possible to show dependencies between regions resulting from physical neighbourhood. The second matrix (W2) allowed for the fact that regions do not have to share a common border to mutually affect each other and the strength of an impact in this case depended on the geographical vicinity of regions. The next matrix (W3) departed from vicinity for actual links between regions. These links were quantified by the volume of freight, which could be affected by distance on the one hand, and by some attractiveness of individual regions, generating economic cooperation on the other. At last, matrix W4 enabled the identification of domestic conditions, recognising regions from the same EU country as neighbours.

The study employed the R programming language (R Studio application), along with QGIS, GeoDa and GRETL open-source software.

Results

The research procedure within the specific to the general modelling strategy started from estimating the conditional β-convergence model Eq. (1) and testing the spatial autocorrelation of regression residuals Eq. (2). The estimated model proved that there was a β-convergence process during the investigated period, and regions with a lower initial growth level achieved statistically faster rates of economic growth (a negative and statistically significant estimation of the parameter with variable LN_GDPpc07). Moreover, the model showed positive effects of Cohesion Policy, which was demonstrated by the positive correlation between the level of EU funds absorption (variable LN_FUNDS) and the economic growth rate of the EU regions. Finally, economic growth dynamics depended on investment, labour resources and the innovativeness level growth rates (positive estimations with variables LN_INVEST, LN_LABOR and LN_INNOV) (Table 1).

[3] Data on trade exchange between EU regions in 2010–2013 come from ESPON EGTC sources and have been devised as part of the project International Relations in Europe (https://database.espon.eu/project-data-package/2911/).

Regardless of the spatial weights matrix used, the research indicated a statistically significant positive spatial autocorrelation of a random component. The values of Moran's index fluctuated from 0.12 for an inverse-distance matrix (W2) to 0.35 for neighbourhood quantified by affiliation of regions with member states (W4). This means that in the case of the investigated process, autocorrelative spatial dependencies are mostly visible between regions within an individual country. It may result from distinct structural parameters of particular national economies and domestic allocation of EU funds. The relatively high values of Moran's index calculated with regard to contiguity (W1) and flow (W3) matrices seem to confirm the above observation.

Autocorrelation of residuals is a sign indicating the existence of spatial effects, which in turn cause changes in the properties of the OLS estimators (Longley et al. 2005). As a result, the application of a spatial approach in modelling conditional convergence was necessary. Lagrange Multiplier tests (LM and RLM) pointed out each time to the SAR model (Table 1).

Spatial modelling substantiated regional β-convergence determined by structural parameters of regional economies and Cohesion Policy implemented by EU funds (Table 2). Simultaneously, the estimated SAR models showed that the growth rate of neighbouring regions was significantly related to the dynamics of economic growth in a given location.

Table 1. Results of conditional β-convergence modelling with the classic OLS method.

Variable	Coefficient	Std. Error	t-Statistic	Probability
CONSTANT	1.068	0.183	5.825	0.0000
LN_GDPpc07	−0.102	0.016	−6.403	0.0000
LN_EU_FUNDS	0.014	0.005	2.675	0.0080
LN_INVEST	0.263	0.015	17.017	0.0000
LN_LABOR	0.483	0.221	2.179	0.0302
LN_INNOV	0.097	0.036	2.659	0.0083
Regression diagnostics				
R^2 = 0.681		JB test = 56.92 (p = 0.0000)		
Log likelihood = 300.256		BP test = 10.07 (p = 0.0773)		
AIC = −588.513		KB test = 4.23 (p = 0.5160)		
Diagnostics for spatial dependence:	Moran's I		Lagrange Multiplier tests	
W1 matrix (contiguity)	0.2740 (p = 0.0000)		$LM_{(SAR)} > LM_{(SEM)}$	$RLM_{(SAR)} > RLM_{(SEM)}$
W2 matrix (distance)	0.1201 (p = 0.0000)		$LM_{(SAR)} > LM_{(SEM)}$	$RLM_{(SAR)} > RLM_{(SEM)}$
W3 matrix (flows)	0.2557 (p = 0.0000)		$LM_{(SAR)} > LM_{(SEM)}$	$RLM_{(SAR)} > RLM_{(SEM)}$
W4 matrix (block)	0.3451 (p = 0.0000)		$LM_{(SAR)} > LM_{(SEM)}$	$RLM_{(SAR)} > RLM_{(SEM)}$

Source: own computation.

Table 2. Results of conditional β-convergence modelling in a spatial approach with the use of a SAR form.

Weights matrix →	W1 (contiguity)		W2 (distance)		W3 (flow)		W4 (block)	
Variable ↓	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
LAG_LN_Y	0.495	0.0000	0.622	0.0000	0.573	0.0000	0.582	0.0000
CONSTANT	0.508	0.0009	0.804	0.0000	0.307	0.0331	0.286	0.0456
LN_GDPpc07	−0.049	0.0002	−0.085	0.0000	−0.033	0.0097	−0.030	0.0154
LN_EU_FUNDS	0.009	0.0423	0.015	0.0024	0.011	0.0055	0.013	0.0008
LN_INVEST	0.162	0.0000	0.209	0.0000	0.114	0.0000	0.130	0.0000
LN_LABOR	0.400	0.0253	0.414	0.0424	0.522	0.0014	0.401	0.0155
LN_INNOV	0.076	0.0010	0.122	0.0003	0.044	0.0108	0.055	0.0499
Pseudo R^2	0.788		0.722		0.802		0.818	
Log likelihood	344.738		317.553		354.265		367.000	
AIC	−675.475		−621.107		−694.53		−720.001	

Source: own computation.

The fact that spatial interactions of the explained variable were taken into account in the convergence analysis improved the quality of fit between the models and empirical data. The values of a log-likelihood for SAR models in each case exceeded the value of the classic model (by analogy, SAR models had lower values of the AIC criterion). Coefficient pseudo-R^2, which measures the share of an explained variance in the total variance, indicates that the model with block matrix W4 is the best fit among the spatial models tested (pseudo-R^2 reaches 0.82). This means that while modelling the conditional convergence process in EU regions, one should consider spatial interactions between regions in individual countries. Taking these dependencies into account ensures that the best fit between the econometric model and empirical data will be obtained, which, according to Openshaw (1977), is an important criterion for the selection of spatial weights matrices. Except for fulfilling statistical criteria, the matrix quantifying national affiliation also seems to be substantively relevant to the problem being solved. This results from the fact that a large proportion of EU funds was allocated to individual member states, i.a. according to their population number, GDP and the unemployment rate. Control variables have national determinants as well, representing other levels, e.g. in new and old EU member states (Pietrzykowski 2019).

To identify spillover effects, the set of explanatory variables is extended by their spatial lags, which is the weighted values of the same variables from neighbouring regions (according to the weights matrices tested in the study). Thus, the second strategy was implemented, and the estimated mixed models are part of the SDM group (Table 3).

The estimated models differed in terms of strength and directions of links as well as the statistical significance of variables. At the same time, spatially lagged variables had higher values of a regression coefficient compared to coefficients for analogous local variables ('spatially non-lagged'). This situation occurred in variables representing the GDP initial state per capita and physical capital. The models showed that EU funds did not affect the dynamics of the regions' economic growth (lack of statistical significance of variables). There were also no effects of spreading growth impulses generated by investments financed from the EU means in the neighbouring regions. On the other hand, some symptoms of the effects of spatial interaction can be observed in the analysis of local and spatially lagged variables measuring labour resources and the level of innovativeness (in models with matrices W1 and W4). While both variables in a local context had a stimulating effect on a region's economic growth, spatial lags of those indicators destimulated the explained variable. This can be interpreted as negative economic effects, consisting in the drain of development resources from less developed to more privileged, better developed regions.

Table 3. Results of conditional β-convergence modelling in a spatial approach with the use of an SDM form.

Weights matrix →	W1 (contiguity)		W2 (distance)		W3 (flow)		W4 (block)	
Variable ↓	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
LAG_LN_Y	0.500	0.0000	−0.903	0.0000	0.278	0.0035	0.651	0.0000
CONSTANT	0.826	0.0001	1.930	0.0004	1.877	0.0000	0.562	0.0086
LN_EU_FUNDS	−0.006	0.3050	0.003	0.5801	0.007	0.2838	0.006	0.1957
LN_GDPpc07	−0.006	0.6663	−0.043	0.0048	−0.028	0.0716	−0.005	0.6844
LN_INVEST	0.126	0.0000	0.155	0.0000	0.128	0.0000	0.098	0.0000
LN_LABOR	0.606	0.0013	0.516	0.0153	0.495	0.0286	0.515	0.0018
LN_INNOV	0.102	0.0028	0.102	0.0054	0.065	0.1355	0.076	0.0505
LAG_LN_GDPpc07	−0.074	0.0003	−0.170	0.0007	−0.156	0.0000	−0.049	0.0188
LAG_LN_EU_FUNDS	0.013	0.0696	0.071	0.0000	0.008	0.4339	-0.002	0.8243
LAG_LN_INVEST	0.030	0.2533	0.539	0.0000	0.167	0.0000	0.018	0.5068
LAG_LN_LABOR	−0.387	0.0699	−0.099	0.9104	0.283	0.5247	−0.618	0.0058
LAG_LN_INNOV	−0.091	0.0520	0.200	0.1080	−0.003	0.9701	−0.079	0.0923
Pseudo R^2	0.828		0.781		0.795		0.865	
Log likelihood	367.079		348.556		357.995		394.95	
AIC	−710.159		−673.112		−691.99		−765.901	

Source: own computation.

The ambiguity in the results of the estimation of SDMs can be found in the fact that the spatial scale of the research (level of NUTS 2 regions) was not adjusted to the actual spatial effects occurring on the side of explanatory variables (e.g. the impact of financial investment from EU funds does not extend beyond a given region). One cannot also exclude the sub-optimal selection of control variables, too short horizons of the analysis or the disturbing impact of the 2007–2009 financial crisis.

Discussion

The obtained outcomes correspond to the research trend formulating positive assessments as to the effectiveness of Cohesion Policy implementation. The results of the research conducted are consistent with the findings of Fiaschi et al. (2018) with respect to the issue of a positive impact of EU funds on the dynamics of economic growth and a reduction of interregional disparities in the European Union. However, in contrast to the above-mentioned work, our analysis did not confirm the existence of spatial effects of spreading growth impulses generated by investments financed from EU funds over the neighbouring territorial units. These discrepancies may result from the different temporal and spatial scopes of the analysis conducted (for the cited work, the research covered EU-12 regions in the years 1991–2008; our analyses refer to the 2007–2013 financial perspective and concern the regions of EU-27) and different constructions of the spatial weights used in econometric models. The discrepancy with respect to the obtained results, arising from the adoption of different temporal and spatial scopes of the analyses, or the differences in the specification of the models applied seem to be typical of research into economic aspects of Cohesion Policy implementation (e.g. Puigcerver-Peñalver 2007; Rodríguez-Pose, Novak 2013).

At the same time, the results achieved in this research fully confirm the findings published by Mohl and Hagen (2010) for two financial perspectives: 1994–1999 and 2000–2006 in the Objective 1 regions of EU-15 states and by Maynou et al. (2016) for the regions of the Eurozone countries in the analysis covering the years 1990–2010. These similarities relate to the pro-development and pro-convergence impact of EU funds as well as the issue of linking the growth rate of the neighbouring regions to the dynamics of economic growth in a given location. The vast majority of conclusions in our analysis have been also confirmed by the findings of Vukašina et al. (2022) with reference to the spending of EU funds in new member states.

Despite the application of different analytical methods, our research results are also consistent with the conclusions presented in European Commission reports on the economic, social and territorial cohesion stating a positive but not very significant impact of EU funds expenditure on economic growth in regions (European Commission 2014, 2017, 2022). These findings are supported by a series of analyses carried out with the use of quasi-experimental methods (Pellegrini et al. 2013; Becker et al. 2018; Blouri, von Ehrlich 2020).

Conclusions

In the light of the research results obtained, the effectiveness of Cohesion Policy implementation in the EU member states was verified. What occurred during the analysed period was a slow conditional β-convergence process between the regions. At the same time, the dynamics of economic growth was determined by the amount of the European funds received per inhabitant. This proves the existence of positive, albeit modest, effects of Cohesion Policy implementation in the investigated period.

The analyses have confirmed the usefulness of the application of SAR models in the description of the studied issue (high values of models' goodness of fit, statistically significant explanatory variables and an impact consistent with economic theory). Based on SAR models, the occurrence of spillover effects of growth impulses onto the surrounding area was confirmed. The growth rate of the neighbouring regions was significantly related to the dynamics of economic growth in a given location.

However, in the context of the analyses concerning the impact of European funds on economic growth at regional level, the usefulness of SDMs was not confirmed. Some explanatory variables turned out to be statistically insignificant at local level. At the same time, spatially lagged variables had higher values of a regression coefficient compared to coefficients for analogous local variables ('non-lagged').

The reasons for this can be attributed to the inadequacy of the regional scale of the research for the spatial effects actually occurring on the side of explanatory variables (e.g. the impact range of financial investments from EU funds does not extend beyond a given region). One cannot also exclude the sub-optimal selection of control variables, too short horizons of the analysis, the disturbing influence of the 2007–2009 financial crisis, etc.

The presented study has certain limitations. Firstly, it should be noted that economic growth is a complex process that depends on various conditions, some of which are not easy to quantify. The net impact of public interventions, including those made with EU funds, is therefore difficult to assess. Econometric models facilitate the description of this relationship. However, they oversimplify reality and often fail to capture its complexity and diversity.

Secondly, the analysis was limited to the financial perspective of 2007–2013, which may restrict the generality of the conclusions. At the same time, the analysis has been aggregated to the financial perspective as a whole. This is because the programming period is coherent in terms of the implementation of regional development strategies.

Thirdly, the spatial scope adopted for the study limited the use of some variables that could potentially affect economic growth dynamics. This is due to the weakness of public statistics and the difficulty of obtaining complete data for all the regions of the EU (e.g. missing data for some regions or different time frames of statistical reporting in individual member states). In the final models, only three control variables (in addition to the value of European funds obtained) were considered to determine economic growth dynamics, although there are known studies where estimated conditional convergence models included much more explanatory variables (Maynou et al. 2016; Fiaschi et al. 2018; Scotti et al. 2022). However, it is important to note that the selection of control variables remains an unsolved problem, despite its crucial role in achieving reliable results and numerous attempts at comprehensive analysis (see i.a. Sala-i-Martin 1997; Hendry, Krolzig 2004; Darlauf et al. 2009).

Finally, it is worth noting that the convergence modelling uses a spatial approach based on cross-sectional data, rather than spatio-temporal analysis and the use of panel models. The latter allows consideration of both the diversity of the studied objects and their evolution over time. However, it was decided to analyse the impact of EU funds in an aggregated form (over a longer period than year to year). Furthermore, the use of panel models was impeded due to modifications of the NUTS2 system during the analysed period, incomplete time series for explanatory variables and periodic fluctuations caused by shocks such as the financial crisis of 2007–2009.

Nevertheless, the research results obtained may be a valuable source of information in the process of Cohesion Policy evaluation. Overall, they confirm the right direction of EU funds spending and the effectiveness of the public intervention they provide. The identified relations may be an argument in the process of planning future pro-development measures as part of modern evidence-based development policies.

The fact that the spatial effects influencing economic growth have been considered in conditional convergence is the added value of this article. The research is one of the few in which spatial interaction is verified by allowing for weights based on matrices of contiguity, distance, flow and affiliation in econometric modelling. The affiliation matrix (block weights) was the best way to incorporate the mechanism of this interaction into the model (stronger effects inside the countries). It is our contention that spatial models are an interesting and promising group of methods, which make it possible to analyse the impact of EU funds on economic growth. The lower level of spatial data aggregation (a country in the system of local units), however, would seem to be a valuable addition to the results presented, owing to the character and spatial scope of these relationships. Further research considering the spatial effects in convergence processes may be also devoted to explaining mechanisms of interaction among the spatial units analysed.

Author's contribution

WK: conceptualisation, investigation, data curation, formal analysis, methodology, writing – original draft, writing – review & editing; BS: conceptualisation, investigation, data curation, formal analysis, methodology, writing – original draft, writing – review & editing.

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