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Spillover Effects of Cohesion Policy and Common Agricultural Policy in Poland: Spatial Panel Data Analysis for 2007–2020

Efekty rozlewania się polityki spójności oraz wspólnej polityki rolnej w Polsce. Analiza na podstawie przestrzennych modeli panelowych w latach 2007–2020

Abstract

Poland joined the European Union in 2004 and, in 2007, became the member state that benefited the most from the bloc's Cohesion Policy, surpassing Spain. Over two financial perspectives, the EU allocated almost EUR 145 billion to Poland between 2007 and 2020. As a country with a significant share of agriculture in its economy, Poland also received substantial support from the Common Agricultural Policy, totalling EUR 50 billion over 14 years. The objective of this study is to assess the spillover effects of the Common Agricultural Policy and the Cohesion Policy on neighbouring NUTS 3 subregions in Poland from 2007 to 2020. Spatial panel methods were applied to evaluate the spillover effects of European funding. The findings suggest the existence of positive local spillover effects of the two policies, but they do not prove the existence of global spillover effects. Additionally, the empirical analysis indicates a positive relationship between European financial support and subregional growth.

Streszczenie

Polska przystąpiła do Unii Europejskiej w 2004 roku, zaś w 2007 roku wyprzedziła Hiszpanię, stając się największym beneficjentem polityki spójności. W ramach dwóch perspektyw finansowych w latach 2007–2020 UE przyznała Polsce niemal 145 mld EUR. Jako kraj o znacznym udziale rolnictwa w gospodarce narodowej, Polska otrzymała również istotne wsparcie w ramach wspólnej polityki rolnej, wynoszące łącznie 50 mld EUR w ciągu czternastu lat. Celem niniejszego badania jest ocena efektów rozlewania się (spillover effect) wspólnej polityki rolnej oraz polityki spójności na sąsiednie podregiony NUTS 3 w Polsce w latach 2007–2020. W analizie ekonometrycznej wykorzystano przestrzenne modele panelowe. Wyniki sugerują istnienie pozytywnych lokalnych efektów rozlewania się polityki spójności oraz wspólnej polityki rolnej, rezultaty jednak nie potwierdzają występowania globalnych efektów rozlewania się obu polityk. Ponadto analiza empiryczna wskazuje na pozytywny wpływ środków unijnych na wzrost gospodarczy podregionów NUTS 3.

Introduction

Poland joined the European Union (EU) along with nine other Central and Eastern European countries as a post-communist economy with low social and economic development. In 2004, Polish GDP per capita was 51% of the EU average, and all NUTS 2 regions were eligible under Objective 1 regions.[1] Additionally, of the five poorest NUTS 2 regions in the EU, four were located in eastern Poland, namely Lubelskie (37%), Podkarpackie (37%), Podlaskie (38%), and Świętokrzyskie (41%); (EUROSTAT).[2]

The weakness of the Polish economy was also reflected in the higher share of agriculture, a less productive sector, in the national Gross Value Added (GVA). In 2004, the GVA produced by agriculture (4.1%) was twice as high as in the EU (2.0%); (AMECO).

Poland's low economic development level has coincided with growing intraregional disparities. In the EU economies of Spain and Italy, regional stratification has manifested as a structural north-south divide [**Czuma, 1973**; **Gagliardi, Percoco, 2011**; **Antunes, Viegas, 2013**]. In Poland, however, the regional differences resemble the development pattern of the less developed East and wealthier West.[3] The main economic problem of Poland's western regions is their limited ability to improve their economic structure and low tendency to innovation, which makes this area less attractive to investors [**Misiąg et al., 2013**; **Gorzelak, 2014**; **Lewandowska, 2016**]. In 2020, the GDP per capita of the five NUTS 2 regions in eastern Poland was lower than 75% of the national average (Statistics Poland).

The relatively low level of economic development and significant regional disparities in Poland justified its broad participation in EU policies. In part, participation in the 2000–2006 financial perspective guaranteed EUR 12.8 billion in structural support. However, in the following planning periods of the Cohesion Policy (CP), Poland became the top recipient of structural funds, surpassing Spain from the 1989–2006 period. In 2007–2013 and 2014–2020, the influx of funds allocated to the Polish economy amounted to EUR 67.2 billion and EUR 77.6 billion respectively [**European Commission, 2007; 2014**]. Additionally, the critical role of agriculture in the economy placed Poland among countries with the highest support from Common Agricultural Policy (CAP) subsidies, which amounted to EUR 50.5 billion from 2007 to 2020 (FADM). Overall, during the 14-year period, EU financial support for Poland amounted to almost EUR 196 billion (see Appendix A1).

This raises the question of what the effect of EU policies is in the largest recipient country. Previous literature presents mixed results. The study by **Misiąg et al.** [**2013**] shows that EU funds had an insignificant effect on regional growth in Poland from 2004 to 2011, while **Kozak** [**2014**] emphasises that, despite EU funds being allocated to reduce development regional differences, there has been no progress in the convergence process across Polish regions. A recent study by **Czudec et al.** [**2019**] shows the positive impact of funds on reducing the development gap in the region of eastern Poland.

The aim of this study is to verify the spillover effects of EU policies across 73 Polish NUTS 3 subregions. The period under consideration includes two financial perspectives of the Cohesion Policy, namely 2007–2013 and 2014–2020. The study uses a neoclassical growth model with externalities across economies [**Ertur, Koch, 2007**]. Spatial panel methods are applied to assess the spillover effects of Common Agricultural Policy (CAP) subsidies and structural funds in Poland. The study considers the financial resources of the CAP and CP jointly, as both policies often operate in the same geographic areas, and their financial resources overlap. This is particularly relevant for regions with agricultural specialisation, which tend to be less developed and suffer from an unfavourable structure dominated by agriculture with slowing productivity [**Cappelen et al., 2003**; **Fuglie, 2018**].

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[1]   Objective 1 regions cover areas with a per capita GDP lower than 75% of the EU average.
[2]   The Nomenclature of Territorial Units for Statistics (NUTS) is a hierarchical system used to subdivide the territory of the European Union (EU) into regions at three different levels (NUTS 1, 2 and 3 respectively, moving from larger to smaller territorial units). The national level of the member state is above NUTS 1. The purpose of NUTS areas is to provide a single and coherent territorial breakdown for compiling regional statistics in the EU.
[3]   Regions of eastern Poland: Warmińsko-mazurskie, Podlaskie, Lubelskie, Świętokrzyskie, Podkarpackie.

The econometric analysis is conducted for three scenarios: in the first two, regressors for CAP subsidies and structural funds are considered separately, while in the third scenario, the regressor covers the combined amount of funding from both sources. Furthermore, the econometric analysis permits distinguishing the spillover effects, underlying their global and local character. In the case of global spillover effects, investment co-financed by EU policies promotes regional growth in all units, while the concept of local spillover effects assumes interaction between border areas.

The contribution of this study to the economic literature is two-fold. First, to the best of the author's knowledge, this study is the first empirical attempt to evaluate the spillover effects of EU policies at the sub-regional level in Poland, the largest beneficiary country during the period of 2007–2020. The findings suggest that EU funding operating in subregions has a positive impact on the growth of border areas. Second, the results of this study contribute to the ongoing debate on the economic effects of EU policies. Spatial techniques, in addition to externalities, provide insight into the direct relationship between EU policies and growth. Some researchers include EU regions without national affiliation, which may result in the loss of vital information on the effects in a particular country [**Le Gallo et al., 2011**; **Antunes et al., 2020**]. Moreover, the sample of regions from several countries characterised by various levels of support, ranging from substantial to insignificant, may lead to an average result that does not correspond to a specific economy. In contrast, this study focuses solely on Poland, where most subregions receive more support than the EU's average, allowing for a more accurate assessment of the effects of EU policies in this country.

The article is organised as follows: Section II provides a brief literature review on the subject. Section III describes the research method, Section IV presents the results, and the study concludes with a discussion.

Literature Review

Economic literature assessing the impact of CP on convergence and growth abounds. However, the results lead to ambiguous conclusions. Recent studies are more optimistic and highlight the positive effect of structural funds in combating regional stratification [**Maynou et al., 2014**; **Cerqua, Pellegrini, 2018**; **Di Cataldo, 2017**; **Fiaschi et al., 2017**; **Giua, 2017**; **Di Caro, Fratesi, 2022**]. Earlier studies, somewhat pessimistic, have highlighted a negative or statistically insignificant relationship between CP and growth or convergence [**Ederveen et al., 2006**; **Bähr, 2008**; **Esposti, Bussoletti, 2008**; **Le Gallo et al., 2011**; **Rodríguez-Pose, Novak, 2013**].

Some authors have attempted to explain why the results are inconclusive by highlighting that the empirical analysis relies on different methodologies, sample sizes or periods, and ignores essential factors influencing regional growth, such as spillover effects [**Hagen, Mohl, 2009**; **Marzinotto, 2012**; **Pieńkowski, Berkowitz, 2015**]. These arguments are consistent with empirical results that show a more substantial impact of CP in Objective 1 regions and more recent data samples [**Dall'Erba, Fang, 2015**], in areas with a less developed service sector [**Percoco, 2017**], in regions with accompanying policies promoting regional development [**Cappelen et al., 2003**], or in rural areas adjacent to urban centres [**Gagliardi, Percoco, 2017**].

Some papers have shifted away from the main focus on the overall effects of CP and pay special attention to factors that guarantee its higher effectiveness, such as human capital and good institutions [**Becker et al., 2013**], the quality of governments [**Rodríguez-Pose, Garcilazo, 2015**], the presence of territorial capital in the regions [**Fratesi, Perucca, 2014**], or administrative capacity [**Surubaru, 2017**].

The authors also investigated the effectiveness of CP by introducing spatial interaction between adjacent areas. However, there is still a need for consensus on the conclusions. **Fiaschi et al.** [**2017**] found significant spillover effects for 175 NUTS 2 regions of EU-12 countries during the period 1991–2008. **Crescenzi and Giua** [**2020**] have demonstrated that the positive effects of CP vary from country to country and are concentrated in Germany or the UK, while the impact in southern countries such as Italy and Spain was limited by the Great Recession. Meanwhile, **Antunes et al.** [**2020**] have shown that the spatial effects of structural funds did not occur between 96 NUTS 2 regions during the 1995–2009 period.

Within empirical analysis, there are few papers that cover both CP and CAP subsidies. **Montresor et al.** [**2011**] confirmed a positive impact of the CAP and CP on labour productivity growth and convergence in 204 NUTS 2 regions of the EU-15, including spatial effects in the β-convergence model. **Esposti** [**2007**], who applied the GMM panel data specification, showed that Objective 1 funds had a positive impact on convergence in 206 regions between 1989 and 2000. While the impact of CAP subsidies did not have a counter-treatment effect on convergence, their impact on growth was weak.

Papers about the effectiveness of Cohesion Policy in Poland show its somewhat limited but positive impact. **Gorzelak and Przekop-Wisznewska** [**2021**] underline that the supply effects of EU programmes are reflected mainly in the "civilisational" aspects of socio-economic life at the local level. **Czudec et al.** [**2019**], using dynamic panel data models, highlight that CP allowed for reducing the regional transport accessibility gap between eastern regions. At the same time, the innovation gap increased. **Lewandowska et al.** [**2015**] based their research on computer-assisted telephone interviews. Relying on the data of small and medium-sized enterprises, they show that structural funds did not positively impact a commitment to investing. In addition, econometric analysis based on panel models has found a positive relationship between structural funds and NUTS 2 regions' growth. However, the role of CP in convergence turned out to be insignificant [**Piętak, 2021**]. Finally, **Biedka et al.** [**2021**], applying the spatial panel model, have shown that investment in human capital co-financed by CP positively affects local revenues in Polish municipalities.

To assess the effectiveness of the CP in Poland, macroeconometric models – Hermin, EUImpactMod, and MaMoR3 – are used at both national and regional levels. The results are presented by comparing two scenarios: the actual performance of the Polish economy and "without funds" simulations, which assume the absence of CP funding. Estimations produced by these models, covering the period from 2004 to 2010, suggest that without structural funds, the annual GDP per capita growth rate would have been lower: Hermin (–3.1%), MaMoR (–3.2%), and EUImpactMod (–3.0%); [**Bukowski et al., 2009**; **Kaczor et al., 2009**; **Zaleski et al., 2009**]. Furthermore, estimates at the NUTS 2 level confirm the positive effect of structural funds in all regions. However, in 2013, the regions that benefited the most in terms of GDP included Warmińsko-mazurskie, Podkarpackie, and Łódzkie [**Zaleski et al., 2007**].

Research method

A growth model with spillover effects

The study uses the neoclassical model, characterised by constant returns to scale and technological externalities to evaluate the spillover effects of European policies in Poland (see Appendix B). The production function of the model includes two types of accumulated capital involved in the production process: physical and human capital. Since structural funds primarily co-finance investment in physical infrastructure and the development of human capital, the study assumes that spatial externalities of European support operate through the level of technology, which depends on the accumulations of these two kinds of capital in neighbouring areas [**Ertur, Koch, 2007**]. Moreover, the view of spatial externalities as technological externalities is adopted by many authors [**López-Bazo et al., 2004**; **De Dominicis, 2014**; **Fiaschi et al., 2017**]. The formula for labour productivity in region *i* is as follows:

$$y_{it} = \Delta_t k_{it}^{\theta k} h_{it}^{\theta h} \left(k_{\rho it}^{\theta k} h_{\rho it}^{\theta h} \right)^{\gamma} \tag{1}$$

where $y_{it} = Y_{it}/L_{it}$, $k_{it} = Y_{it}/K_{it}$, $h_{it} = H_{it}/L_{it}$ are output, physical and human capital per unit of labour respectively. θ_k and θ_h are marginal internal returns to physical and human capital respectively. The parameters $k_{\rho it}$ and $h_{\rho it}$ are physical and human capital in neighbouring regions, and γ measures the externalities across economies. According to Equation (1), the labour productivity of the *i* region depends on the stock of physical and human capital and the accumulation of this capital in border areas. The impact of the externalities is expressed as $\gamma\theta k$ and $\gamma\theta h$.

Considering Equation (1) and applying a first-order Taylor expansion around the steady state, the convergence equation for this model is as follows:

$$Growth = \xi - (1 - e^{-\beta T})\ln y_0 + \frac{(1 - e^{-\beta T})\gamma}{1 - (\theta_k + \theta_h)}\ln y_{0\rho} + \gamma g_{y_\rho} + \frac{(1 - e^{-\beta T})}{1 - (\theta_k + \theta_h)} + \qquad (2)$$

$$\frac{(1 - e^{-\beta T})}{1 - (\theta_k + \theta_h)}[\theta_k(\ln s_k - \ln(n + g + \delta)) + \theta_h(\ln s_h - \ln(n + g + \delta))]$$

where *Growth* is the growth rate of labour productivity between periods 0 and T, y_0 denotes the level of labour productivity at the initial time 0, $\beta = (1 - \tau_k - \tau_h)(n + g + \delta)$ is the rate of convergence, $\xi = (1 + \gamma)g - (1 - e^{-\beta T})\left(1 - \frac{\gamma}{1 - (\theta_k + \theta_h)}\right)(\ln\Delta_0 + gT)$, and δ is the rate of capital depreciation ($\delta = \delta_k = \delta_h$). According to Equation (2), labour productivity growth in the steady state inversely depends on its initial level ($\theta_k + \theta_h < 1$) and is positively related to labour productivity in neighbouring regions ($\gamma > 0$). That means that the "quality" of regions matters. Regions surrounded by areas with high larger initial productivity and higher rates of productivity growth will develop faster than regions deprived of such a favourable location.

Given a certain group of units *N*, time periods *T*, Equation (2) can be rewritten as the Spatial Durbin Model (SDM) growth equation in the steady state:

$$Growth = const - (1 - e^{-\beta T})\ln y_0 + \lambda(1 - e^{-\beta T})W\ln y_0 + \lambda WGrowth \qquad (3)$$

$$+ bX + \theta WX + e$$

where *const* collects different steady states across regions, y_0 and *Growth* are $N \times 1$ column vectors with observations for the initial level of productivity per worker and growth for the sample of units, λ is the spatial autoregressive coefficient, *X* is the set of covariates, (θWX) is the Durbin component, *W* is the weight matrix describing the proximity between units, and *e* is an error term.

In the case of the spatial correlation in residuals, Equation (3) takes the form of the Durbin Spatial Error Model (SDEM):

$$Growth = (I - \lambda W)const - (1 - e^{-\beta T})\ln y_0 + \lambda(1 - e^{-\beta T})W\ln y_0 \qquad (4)$$

$$+ \lambda WGrowth + bX + \theta WX + u$$

$$e = \lambda We + u$$

where λ is the parameter of spatial autocorrelation of residuals, and other symbols are as defined above. According to Equations (3) and (4), the transition of the economy toward a steady state depends on its initial level of income, as well as the initial level and growth in border areas.

Methodological approach

The study assesses spillover effects, taking into account their global and local character. Aselin [2003] emphasises that the difference between the two spatial effects stems from their scope. Due to the feedback loop, global spillover effects are transmitted to all regions in the data sample, even those that do not share a common border. Local spillover effects only operate in connected regions. To track global spillover effects, the study uses the SDM model (Equation 3), which can be described in vector form as [**LeSage, 2014**]:

$$Growth_{i,t} = \rho WGrowth_{i,t} + \beta X_{i,t} + \theta WX_{i,t} + a_i + \delta_t + e_{i,t} \qquad (5)$$

where $i = 1,2,...n$, $t = 1,2,..., T$, the subscript *i* and *t* represent subregional units and time respectively. $Growth_{i,t}$ is the vector of observation on the dependent variable, ρ denotes the spatial autoregressive coefficient, $X_{i,t}$ is

a $K \times 1$ vector of exogenous regressors, and β and θ represent a $K \times 1$ vector of unknown parameters, a_i and δ_t represent country- and time-specific fixed effects respectively. W is a nonnegative $N \times N$ weight matrix that describes the neighbourhood between units, and $e_{i,t}$ is the independent and identically distributed error term.

A positive and statistically significant value of ρ indicates the existence of clusters of similar regions. A negative value of the coefficient reflects dissimilarity, which could be reflected in regional competition or the backwash effect [**Kao, Bera, 2013**]. Since the dependent variable appears on both sides of Equation (5), to control for the endogeneity problem, the estimates are based on the maximum likelihood estimator [**Elhorst, 2014**].

After rewriting the SDM model, we obtain:

$$Growth_{i,t} = (I - \rho W)^{-1}\beta X_{i,t} + (I - \rho W)^{-1}\theta W X_{i,t} + (I - \rho W)^{-1}(a_i + \delta_t + e_{i,t}) \tag{6}$$

where the parameter $(I - \rho W)^{-1}$ represents a feedback loop, indicating that changes in the regressor of one region do not only impact border areas but all units in the sample. In the case of the SDM model, coefficients do not directly reflect the marginal effects of regressors. As stressed by **Le Sage and Pace** [**2008**], the total effect is the sum of effects over the row of the matrix $(I - \rho W)^{-1}$. The direct effect is the sum of the diagonal elements of the matrix $(I - \rho W)^{-1}$, while the indirect effect (spillover effect) is given by the difference between the total effect and the direct effect[4].

Two econometric specifications are considered to assess the local spillover effects. Equations (7) and (8) present the *Spatially Lagged X* model (SLX) and the *Spatial Durbin Error Model* (SDEM) respectively:

$$Growth_{i,t} = \beta X_{i,t} + \theta W X_{i,t} + a_i + \delta_t + e_{i,t} \tag{7}$$

$$Growth_{i,t} = \beta X_{i,t} + \theta W X_{i,t} + a_i + \delta_t + u_{i,t} \tag{8}$$

$$u_{i,t} = \lambda W u_{i,t} + e_{i,t}$$

where λ is the spatial autoregressive parameter representing regional characteristics that are difficult to measure and not included in the regressors, while $u_{i,t}$ is an error term. A statistically significant and positive value of λ suggests the presence of unobserved spatial patterns, such as language, culture or social capital. A negative value of λ indicates the existence of competitive mechanisms of reaction to shocks that are captured by the error term. Other symbols are as defined above. Both models track local spillover effects while controlling for the Durbin component ($\theta W X$). The *Unemploy* coefficient expresses the direct effect, and θ represents the indirect effect.

The spatial weight matrix, W, is constructed in two ways in the study. First, the contiguity matrix is based on the common boundary criterion, where w_{ij} is the element of the spatial contiguity matrix, W, such that $w_{ij} = 1$ if regions i and j are neighbours and $w_{ij} = 0$ otherwise, regardless of the border length. Following the general convention, the matrix is row-standardised to 1.

Second, the spatial weight matrix, W, is a binary matrix equal to 1 in the case of the k – nearest neighbouring regions, with $k = 7$, and 0 otherwise. The second matrix is used in the robustness check of estimations.

Data

The annual data used in the study were obtained from the following sources. The data on Polish NUTS 3 subregions were retrieved from the Local Data Bank database of Statistics Poland. The list of investments co-financed by structural funds in Poland was published by the Ministry of Development Funds and Regional Policy. The Agency for Restructuring and Modernisation of Agriculture (ARMA) provided the value of CAP

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4   When comparing the models of local spillover effects (Equations 7 and 8) and global spillover effects (Equation 5), the main difference lies in the structure of the matrix W. In the case of the SLX and SEDM specifications, the matrix W contains elements equal to zero, except when regions share a common border. In the case of the SDM model, the matrix $(I - \rho W)^{-1}$ does not contain elements equal to zero, and changes in explanatory variables have effects in all regions.

subsidies in Poland upon prior request.[5] As the spatial regression programme used in the study (in R statistics) does not allow missing values in the panel data, all missing values were replaced with zero to balance the panel.[6]

All the regressors in the study were transformed into logarithmic values. The dependent variable is the annual growth rate of GDP per capita ($Growth_{i,t}$) of subregion i at time t. The models also include several control variables. The variable $GDPpc_{t-1}$ represents the initial value of GDP per capita in NUTS 3 subregions in 2005 constant prices in euros.[7] The financial resources of EU policies are also included as key variables. The covariates *Agri* and *Fund* represent the annual average value of CAP subsidies and structural funds per capita (in euros) respectively. The variable *Agrifund* denotes the combined value of these two variables.

Another relevant variable included in the model is investment (*Invest*), which has been found to have a positive relationship with regional growth in previous empirical studies [**Mas et al., 1996**; **Pereira, Roca Sagalés, 2003**; **Rodríguez-Pose et al., 2012**]. Since the gross fixed capital formation value is not reported in national statistics at the subregion level, investment is proxied as the investment outlays in enterprises expressed in euros per capita in 2005 constant prices.

The econometric analysis also considers unemployment (*Unemploy*), as people without work do not contribute to growth. The variable $(n + \delta + g)$ is the combined growth rate of (n), capital depreciation (δ) and exogenous technical progress (g), where the term $(\delta + g)$ is equal to 0.05 (see **Mankiw, Romer, Weil** [**1992**]]. The negative signs of the two variables are expected.

Two variables, population density (*Dens*) and the existence of a big city (*Bigcity*), are related to the agglomeration concept. Population density measures the number of people per square kilometre, while the variable *Bigcity* is the dummy variable with a value of 1 if there is a city in the subregion with more than 250,000 inhabitants, and 0 otherwise.[8] As scholars have stressed, the average city size and population growth increase productivity and economic growth [**Fujita, Thisse, 2002**; **Castells-Quintana, Royuela, 2014**; **OECD, 2016**; **Frick, Rodríguez-Pose, 2016**].

The study also considers the geographical location of the units. The dummy variable *EastPol* has a value of 1 if the subregion is located in NUTS 2 regions of eastern Poland; otherwise, it has a value of 0. The negative value of the coefficient confirms that the location in the poorer part of Poland hinders economic development.

Table A1 presents the variables that were included in the models, along with their definitions and sources of extraction (see Appendix C). Table A2 presents descriptive statistics for the covariates. The mean amount of structural funds per capita was EUR 191.40, with a minimum value of EUR 104.30 and a maximum value of EUR 403.30. The CAP subsidies variable had a mean value of EUR 100.10, with a minimum value of EUR 0.20 and a maximum value of EUR 306. Figure A1 illustrates the spatial allocation of EU policy funds in the Polish NUTS 3 subregions.

Results

Empirical results

Here, the study presents the empirical results. The starting point of the empirical analysis is the estimation of non-spatial panel data models. Table 1 presents relevant parameter estimates using the OLS estimator and spatial and period fixed effect estimator. The **Breusch-Pagan** [**1980**] test suggests rejecting the OLS

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[5]   The author would like to thank the ARMA authorities for sharing data on CAP subsidies in Poland.

[6]   In the case of the data used in the study, there is no unemployment data available for the years 2007–2010 for the following subregions: Żyrardowski, Siedlecki, Warszawa Zachodnia, and Warszawa Wschodnia.

[7]   The Local Data Bank of Poland provides statistics on the GDP per capita of NUTS 3 subregions in current prices using the Polish currency (PLN). To conduct the study, the data were adjusted to constant prices (2005) based on the inflation rate listed on the National Bank of Poland's website. Following this, the data were converted into euros using the exchange rate applicable on the last day of the year (December 31).

[8]   Between 2007 and 2020, there were 16 cities in Poland with populations greater than 200,000: Warszawa (1,792,718), Kraków (780,796), Łódź (667,923), Wrocław (641,201), Poznań (530,464), Gdańsk (470,633), Szczecin (396,472), Bydgoszcz (341,692), Lublin (337,788), Białystok (296,401), Katowice (289,162), Gdynia (244,104), Częstochowa (215,905), Radom (208,091), and Rzeszów (198,476).

estimator, and the **Hausman** [**1978**] test indicates that the random effect model should be rejected in favour of a fixed effect specification. Therefore, the fixed effect estimator was chosen for further econometric analysis. Additionally, **Elhorst** [**2003**] stresses that fixed effect specification is more appropriate for spatial analysis than the random effects model.

Table 1 also presents the results of the LM and robust LM tests that verify the possibility of introducing spatial components into the econometric analysis [**Anselin, 1988**; **Elhorst, 2003**]. However, the results of these tests are inconclusive. The LM test rejects the null hypothesis of no spatially lagged dependent variable and the absence of a spatially correlated error term ($q < 0.05$). In contrast, the robust LM test for spatial lag and spatial error specification allows rejection of the null hypothesis, providing evidence of the presence of spatial dependence ($q > 0.05$). As all regressors are spatially autocorrelated and tracking spillover effects requires covering spatial elements, I proceed with spatial specification, paying exceptional attention to the significance of spatial coefficients in the econometric outcomes (see Appendix C3).

In relation to the fixed effect estimator (models 4-6), the variables *Fund* and *Agrifund* have positive and statistically significant signs, confirming the positive relationship between EU policies and growth. The variable *Agri*, which covers only CAP subsidies, is positive but insignificant.

The variable *GDPpc* is negative and statistically significant at the 1% significance level, confirming convergence across subregions. This means that poorer regional economies are developing faster than the richer ones. Additionally, the positive value of investment (*Invest*) and the presence of a big city (*Bigcity*) align with expectations. The negative signs of the *Unemploy* and $n + \delta + g$ regressors are also in line with expectations.

The results suggest that being located in the eastern part of Poland has an adverse impact on growth. The dummy variable *EastPol* is negative and significant in all models. However, the variable of population density has an unexpected negative and significant sign.

Tables

Table 1. Panel OLS models and spatial dependence tests

Dep. variable: Growth	Pooled OLS			Spatial and time-period fixed effects		
	1	2	3	4	5	6
Const	0.2982*** 0.0656)	0.2478*** (0.0687)	0.2399*** (0.0683)			
$GDPpc_{t-1}$	−0.0318*** (0.0072)	−0.0309*** (0.0071)	−0.0307*** (0.0071)	−0.0193** (0.0063)	−0.0196*** (0.0061)	−0.0192*** (0.0061)
Agri	−0.0005 (0.0010)			0.0004 (0.0008)		
Fund		0.0087* (0.0044)			0.0097** (0.0033)	
Agrifund			0.0097* (0.0040)			0.0101*** (0.0029)
Invest	0.0097* (0.0037)	0.0083* (0.0038)	0.0087* (0.0038)	0.0101*** (0.0029)	0.0088** (0.0030)	0.0092** (0.0029)
Unemploy	−0.0040 (0.0024)	−0.0037 (0.0023)	−0.0044 (0.0023)	−0.0061** (0.0020)	−0.0051** (0.0019)	−0.0061** (0.0019)
$n + \delta + g$	0.0005 (0.0048)	−0.0011 (0.0049)	0.0002 (0.0048)	−0.0281*** (0.0046)	−0.0303*** (0.0047)	−0.0288** (0.0046)
Dens	−0.0014 (0.0049)	−0.0015 (0.0045)	0.0012 (0.0045)	−0.0090* (0.0037)	−0.0108** (0.0035)	−0.0079* (0.0035)
Bigcity	0.0092* (0.0040)	0.0086* (0.0035)	0.0099** (0.0034)	0.0095*** (0.0029)	0.0072** (0.0026)	0.0085** (0.0026)
EastPol	−0.0043 (0.0028)	−0.0079* (0.0033)	−0.0078* (0.0031)	−0.0038* (0.0021)	−0.0076** (0.0025)	−0.0071** (0.0023)
Observations	1022	1022	1022	1022	1022	1022

Dep. variable: Growth	Pooled OLS			Spatial and time-period fixed effects		
	1	2	3	4	5	6
N R²	73 0.21	73 0.21	73 0.021	73 0.35	73 0.35	73 0.36
F-statistic	29.33 (0.0000)	29.56 (0.0000)	29.87 (0.0000)	74.08 (0.0000)	75.47 (0.0000)	76.2 – (0.0000)
LM spatial lag	3.4291 (0.0640)	3.7256 (0.0511)	3.8588 (0.0494)	4.9526 (0.0260)	4.6371 (0.0312)	4.9629 (0.0259)
Robust LM spatial lag	0.6422 (0.4229)	0.1596 (0.6895)	0.7319 (0.3923)	0.8060 (0.3693)	0.5349 (0.4646)	1.6312 (0.2015)
LM spatial error	3.128 (0.0769)	3.5906 (0.0581)	3.4909 (0.0617)	4.3673 (0.0366)	4.1882 (0.0407)	4.0189 (0.0449)
Robust LM spatial error	0.3410 (0.5592)	0.2371 (0.8774)	0.3440 (0.5463)	0.2209 (0.6383)	0.0859 (0.7694)	0.6872 (0.4007)
Breusch-Pagan	6710.3 (0.0000)	6789.1 (0.0000)	6791.1 (0.0000)	–	–	–
Hausman Test	–	–	–	157.1 (0.0000)	215.7 (0.0000)	224.7 (0.0000)

Notes: The dependent variable is GDP per capita growth (*growth*). Standard errors in parenthesis. *q < 0.1 denotes significance at 10% level. **q < 0.05 denotes significance at 5% level. ***q < 0.01 denotes significance at 1% level.

Source: Author's own elaboration.

Table 2 presents the estimates of the SDM model, which allows for tracking global spillover effects. The coefficient of the lagged dependent variable (ρ) is positive but statistically insignificant in all models, suggesting that the growth pattern in neighbouring subregions does not significantly impact local economic growth. This finding is consistent with previous analyses based on Moran's I statistic, which confirmed the absence of spatial interdependencies of the dependent variable (see Appendix A3). These results imply that subregions with similar economic growth are not concentrated geographically.

Regarding the key variables of EU policies, once again, the covariates of structural funds (*Fund*) and the coupled value of CAP subsidies and structural funds (*Agrifund*) are positive and significant, confirming the positive influence of EU funding on growth. However, the variable that expresses only the amount of CAP subsidies is insignificant.

The variable of GDP per capita (*GDPpc*) is negative and significant, providing evidence of convergence. Additionally, the estimates show a positive and statistically significant relationship between investment and big cities, as well as an adverse effect of unemployment and the combined population growth rate, capital depreciation, and exogenous technical progress on economic growth. The covariates of density and the dummy variables distinguishing eastern Poland subregions are statistically insignificant.

Table 2. Results of the SDM model

Dep. variable: Growth	1	2	3
Rho(ρ)	0.0195 (0.0404)	0.0156 (0.0403)	0.0162 (0.0404)
GDPpc$_{t-1}$	−0.0423*** (0.0078)	−0.0428*** (0.0076)	−0.0420*** (0.0066)
Agri	0.0009 (0.0012)		
Fund		0.0152*** (0.0045)	
Agrifund			0.0109* (0.0052)
Invest	0.0095** (0.0034)	0.0086* (0.0035)	0.0093** (0.0035)

cont Table 2

Dep. variable: Growth	1	2	3
Unemploy	−0.0061* (0.0029)	−0.0034 (0.0029)	−0.0049 (0.0028)
$n + \delta + g$	−0.0152* (0.0064)	−0.0144* (0.0062)	−0.0117 (0.0062)
Dens	0.0090 (0.0058)	−0.0047 (0.0055)	−0.0094 (0.0057)
Bigcity	0.0131** (0.0047)	0.0092* (0.0044)	0.0124** (0.0043)
EastPol	0.0034 (0.0057)	−0.0025 (0.0060)	−0.0001 (0.0059)
$W \times GDPpc_{t-1}$	−0.0484*** (0.0112)	−0.0486*** (0.0111)	−0.0477** (0.0112)
W × Agri	−0.0059* (0.0027)		
W × Fund		−0.0003 (0.0096)	
W × Agrifund			−0.0058 (0.0083)
W × Invest	−0.0187** (0.0057)	−0.0164** (0.0058)	−0.0164 (0.0058)
W × Unemploy	−0.0043 (0.0039)	−0.0060 (0.0038)	−0.0051 (0.0038)
$W \times n + \delta + g$	0.0459*** (0.0080)	0.0431*** (0.0076)	0.0423*** (0.0077)
W × Dens	0.0252** (0.0082)	0.0304** (0.0073)	0.0312*** (0.0074)
W × Bigcity	−0.0031 (0.0134)	0.0022 (0.0116)	0.0081 (0.0117)
W × EastPol	−0.0214** (0.0075)	−0.0256** (0.0079)	−0.0250** (0.0078)
Observations	1022	1022	1022
N	73	73	73
R²	0.35	0.35	0.35
Log lik	2216.8	2220.0	2216.6
AIC	−4223.7	−4230.1	−4223.6

Notes: Standard errors in parenthesis. *q < 0.1 denotes significance at 10% level. **q < 0.05 denotes significance at 5% level. ***q < 0.01 denotes significance at 1% level.

Source: Author's own elaboration.

Table 3. Marginal effects of the SDM model

	Agri			*Fund*			*Agrifund*		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
$GDPpc_{t-1}$	−0.0423*** (0.0074)	−0.0008 (0.0018)	−0.0432*** (0.0079)	−0.0428*** (0.0076)	−0.0007 (0.0018)	−0.0437*** (0.0081)	−0.0420*** (0.0211)	−0.0008 (0.0204)	−0.0428*** (0.0410)
Agri	0.0007 (0.0013)	0.0001 (0.0001)	0.0008 (0.0014)						
Fund				0.0152*** (0.0045)	0.0002 (0.0006)	0.0155*** (0.0046)			
Agrifund							0.0109* (0.0064)	0.0002 (0.0060)	0.0111* (0.0124)
Invest	0.0095** (0.0036)	0.0001 (0.0001)	0.0097** (0.0037)	0.0086* (0.0036)	0.0001 (0.0003)	0.0087* (0.0038)	0.0093* (0.0130)	0.0002 (0.0125)	0.0095* (0.0255)
Unemploy	−0.0061* (0.0028)	−0.0001 (0.0001)	−0.0063* (0.0029)	−0.0034 (0.0028)	−0.0001 (0.0001)	−0.0035 (0.0028)	−0.0049 (0.0130)	−0.0001 (0.0125)	−0.0050 (0.0255)

cont Table 3

	Agri			Fund			Agrifund		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
$n+\delta+g$	−0.0152* (0.0062)	−0.0003 (0.0001)	−0.0155* (0.0063)	−0.0144* (0.0060)	−0.0002 (0.0006)	−0.0147* (0.0062)	−0.0117 (0.0130)	−0.0002 (0.0125)	−0.0120 (0.0255)
Dens	0.0090* (0.0059)	0.0002 (0.0001)	0.0092* (0.0060)	0.0047 (0.0060)	0.0001 (0.0003)	0.0048 (0.0061)	0.0091 (0.0130)	0.0002 (0.0125)	0.0093 (0.0255)
Bigcity	0.0131* (0.0052)	0.0002 (0.0001)	0.0133* (0.0053)	0.0092* (0.0045)	0.0002 (0.0004)	0.0094* (0.0047)	0.0124** (0.0130)	0.0002 (0.0125)	0.0127** (0.0255)
EastPol	0.0001 (0.0058)	0.0001 (0.0001)	0.0001 (0.0060)	−0.0025 (0.0061)	−0.0001 (0.0002)	−0.0026 (0.0062)	−0.0034 (0.0058)	−0.0001 (0.0001)	−0.0034 (0.0060)

Notes: Standard errors in parenthesis. *q < 0.1 denotes significance at 10% level. **q < 0.05 denotes significance at 5% level. ***q < 0.01 denotes significance at 1% level.

Source: Author's own elaboration.

The coefficients of the SDM model do not express the direct impact of the regressors on the dependent variable.[9] Table 3, with marginal effects, is presented for a correct interpretation of the results. The results are divided into direct, indirect, and total effects. However, the insignificant value of the spatially lagged dependent variable (ρ) implies insignificant changes in the results. None of the covariates confirm global spillover effects; the indirect effect of variables is statistically insignificant. The results suggest a positive and statistically significant direct and total impact of CAP subsidies and structural funds on growth.

The next point of the empirical analysis verifies the existence of local spillover effects of EU policies. Table 4 presents the results of Equations (7) and (8). The local spillover effects are modelled with the lags of regressors (θWX) of the SDEM and SLX models. In the case of the SDEM model, the spatial autoregressive parameter λ is negative and statistically significant, confirming the competitive pattern between units modelled by the error term. Estimates of both specifications show a positive and significant impact of covariates (*Fund*) and (*Agrifund*) on growth and insignificant relationship between CAP subsidies and growth. Estimates again confirm the convergence process across subregions; the variable (*GDPpc*) is negative and statistically significant in all models. The positive and significant signs are estimated for the investment and big city variables.

Regarding the local spillover effect, the SLX specification suggests the positive and significant effect of the regressor $W \times Fund$, which means that funds operating in a given area impact growth in border areas. Other variables of European policies, namely $W \times Agri$ and $W \times Agrifund$, are statistically insignificant and do not confirm the spillover effects on the borders subregions. The SDEM model's outcomes show a lack of spatial effects of European policies; all variables are statistically insignificant. However, the estimates confirm positive and significant values of regressors $W \times Dens$ and $W \times n + \delta + g$, confirming the local spillover effect. In turn, sharing a border with a subregion of eastern Poland harms growth; and the covariate $W \times EastPol$ is negative and significant.

Table 4. Results of the SDEM and SLX models

Dep. variable: growth	SDEM model			SLX model		
	1	2	3	4	5	6
Lambda(λ)	−0.0959* (0.0435)	−0.0981* (0.0435)	−0.0954* (0.0435)			
$GDPpc_{t-1}$	−0.0324*** (0.0075)	−0.0340*** (0.0074)	−0.0336*** (0.0074)	−0.0227*** (0.0065)	−0.0228*** (0.0064)	−0.0223*** (0.0064)
Agri	0.0009 (0.0012)			−0.0006 (0.0010)		
Fund		0.0073* (0.0038)			0.0088* (0.0034)	

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9   There are some problems with extracting "impacts" in spatial panel data models. The spatialreg package does not produce them, as it does with cross-sectional data. The estimation results were obtained using the spdep (0.5-56) and splm (1.4-11) packages in R software.

cont Table 4

Dep. variable: growth	SDEM model			SLX model		
	1	2	3	4	5	6
Agrifund			0.0046 (0.0049)			0.0079* (0.0039)
Invest	0.0089** (0.0034)	0.0085* (0.0034)	0.0088* (0.0034)	0.0109*** (0.0030)	0.0101*** (0.0030)	0.0104*** (0.0030)
Unemploy	−0.0070* (0.0028)	−0.0052* (0.0028)	−0.0061* (0.0028)	−0.0054* (0.0024)	−0.0041* (0.0024)	−0.0051* (0.0023)
$n + \delta + g$	−0.0169** (0.0065)	−0.0153* (0.0062)	−0.0143* (0.0062)	−0.0239*** (0.0055)	−0.0262*** (0.0052)	−0.0256*** (0.0052)
Dens	0.0006 (0.0051)	−0.0026 (0.0047)	−0.0003 (0.0049)	0.0105* (0.0042)	0.0115*** (0.0039)	0.0085** (0.0041)
Bigcity	0.0131** (0.0044)	0.0102* (0.0041)	0.0120** (0.0040)	0.0090* (0.0037)	0.0072* (0.0032)	0.0098** (0.0031)
EastPol	−0.0028 (0.0045)	−0.0061 (0.0047)	−0.0046 (0.0046)	−0.0029 (0.0037)	−0.0057 (0.0039)	−0.0045 (0.0038)
$W \times GDPpc_{t-1}$	−0.0533*** (0.0112)	−0.0532*** (0.0112)	−0.0527*** (0.0112)	−0.0292** (0.0132)	−0.0240* (0.0131)	−0.0283** (0.0131)
$W \times Agri$	−0.0022 (0.0020)			0.0028 (0.0017)		
$W \times Fund$		0.0060 (0.0083)			0.0150* (0.0069)	
$W \times Agrifund$			0.0001 (0.0066)			0.0071 (0.0054)
$W \times Invest$	−0.0083 (0.0054)	−0.0076 (0.0055)	−0.0074 (0.0055)	−0.0096* (0.0052)	−0.0083 (0.0052)	−0.0073 (0.0052)
$W \times Unemploy$	−0.0044 (0.0039)	−0.0062 (0.0038)	−0.0057 (0.0038)	0.0001 (0.0039)	0.0001 (0.0038)	−0.0003 (0.0038)
$W \times n + \delta + g$	0.0528*** (0.0080)	0.0486*** (0.0077)	0.0493*** (0.0076)	−0.0128 (0.0088)	−0.0163* (0.0082)	−0.0149* (0.0081)
$W \times Dens$	0.0264*** (0.0065)	0.0280*** (0.0061)	0.0276*** (0.0062)	−0.0029 (0.0059)	−0.0062 (0.0057)	−0.0078 (0.0058)
$W \times Bigcity$	0.0096 (0.0114)	0.0114 (0.0105)	0.0143 (0.0106)	−0.0003 (0.0093)	−0.0088 (0.0087)	−0.0046 (0.0088)
$W \times EastPol$	−0.0126* (0.0062)	−0.0143* (0.0072)	−0.0132* (0.0068)	−0.0013 (0.0055)	−0.0058 (0.0060)	−0.0037 (0.0067)
Observations	1022	1022	1022	1022	1022	1022
N R²	73 0.31	73 0.32	73 0.31	73 0.34	73 0.34	73 0.34
F-statistic	–	–	–	47.02 (0.0000)	47.02 (0.0000)	47.02 (0.0000)
Log lik	–	–	–	–	–	–

Notes: Standard errors in parenthesis. *q < 0.1 denotes significance at 10% level. **q < 0.05 denotes significance at 5% level. ***q < 0.01 denotes significance at 1% level.

Source: Author's own elaboration.

Robustness check of the results

The robustness of the results is tested by using a different set of explanatory variables and a new weight matrix. The covariates related to European policies, which were previously expressed as per capita values, are now expressed as a share of regional GDP. Additionally, the new investment regressor (*Invest%*) is expressed as a percentage of GDP. The population density variable is replaced by the share of the population living in urban areas (*City%*). Finally, the *Bigcity* dummy variable is replaced by the share of services in regional GVA (*Service%*). Furthermore, a new weight matrix, *W*, is constructed using the k-nearest neighbour method.

Table 5. Results of the SDM model (weight matrix, k- nearest neighbour, with $k=7$)

Dep. variable: Growth	1	2	3
$Rho(\rho)$	−0.0523 (0.0661)	−0.0449 (0.0656)	−0.0388 (0.0658)
$GDPpc_{t-1}$	−0.0154* (0.0072)	−0.0117 (0.0079)	−0.0117 (0.0079)
Agri%	0.0038 (0.0028)		
Fund%		0.0128** (0.0046)	
Agrifund%			0.0138** (0.0047)
Invest%	0.0099** (0.0035)	0.0090* (0.0035)	0.0087* (0.0035)
Unemploy	−0.0063** (0.0024)	−0.0050* (0.0024)	−0.0048* (0.0024)
$n+\delta+g$	−0.0241*** (0.0054)	−0.0256*** (0.0054)	−0.0233*** (0.0054)
City%	0.0079 (0.0054)	0.0019 (0.0023)	−0.0051* (0.0024)
Service%	0.0189* (0.0101)	0.0071 (0.0098)	−0.0009 (0.0102)
Dummyeast	0.0033 (0.0054)	−0.0048 (0.0048)	−0.0052 (0.0045)
$W \times GDPpc_{t-1}$	−0.0870*** (0.0158)	−0.0598*** (0.0174)	−0.0527*** (0.0185)
$W \times$ Agri%	0.0089 (0.0086)		
$W \times$ Fund%		0.0435** (0.0141)	
$W \times$ Agrifund%			0.0530** (0.0162)
$W \times$ Invest%	−0.0174* (0.0080)	−0.0222** (0.0082)	−0.0216** (0.0081)
$W \times$ Unemploy	−0.0078 (0.0042)	−0.0114* (0.0045)	−0.0122** (0.0045)
$W \times n+g$	0.0768*** (0.0084)	0.0767*** (0.0083)	0.0748*** (0.0083)
$W \times$ City%	0.0391** (0.0147)	0.0209*** (0.0051)	0.0339*** (0.0058)
$W \times$ Service%	−0.0614* (0.0298)	−0.0962* (0.0307)	−0.0989** (0.0301)
$W \times$ Dummyeast	0.0011 (0.0093)	−0.0162 (0.0099)	−0.0061 (0.0090)
Observations	1022	1022	1022
N	73	73	73
R²	0.38	0.39	0.39
Log lik	2248.1	2254.8	2255.2
AIC	−4286.1	−4299.6	−4300.4

Notes: Standard errors in parenthesis. *q < 0.1 denotes significance at 10% level. **q < 0.05 denotes significance at 5% level. ***q < 0.01 denotes significance at 1% level.

Source: Author's own elaboration.

Table 5 presents the results of the SDM model with the new set of covariates and weight matrix. However, the changes in the specification do not affect the estimates of the key variables. The results confirm a positive and significant relationship between structural funds, coupled amounts of CAP subsidies and funds, and

growth. However, the variable of CAP subsidies remains insignificant. The insignificant value of the lagged dependent variable (ρ) affects the results of marginal effects, which are presented in Table 6. The estimates show that there is a positive and significant direct and total effect of structural funds and the coupled value of European policies, but the indirect effect of all key variables is insignificant. Therefore, it cannot be concluded that CAP subsidies and structural funds confirm the global spillover effects across Polish NUTS 3 subregions.

Table 6. Marginal effects of the SDM model (weight matrix, k- nearest neighbour, with *k*=7)

	Agri			Fund			Agrifund		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
$GDPpc_{t-1}$	−0.0154* (0.0076)	0.0007 (0.0011)	−0.0146* (0.0072)	−0.0117 (0.0081)	0.0005 (0.0009)	−0.0112 (0.0078)	−0.0117 (0.0073)	0.0004 (0.0009)	−0.0112 (0.0069)
Agri%	0.0038 (0.0027)	−0.0001 (0.0003)	0.0036 (0.0025)						
Fund%				0.0128** (0.0047)	−0.0005 (0.0009)	0.0122** (0.0046)			
Agrifund%							0.0138** (0.0051)	−0.0005 (0.0009)	0.0133** (0.0050)
Invest%	0.0099** (0.0037)	−0.0004 (0.0006)	0.0094* (0.0035)	0.0090* (0.0035)	−0.0003 (0.0006)	0.0086* (0.0034)	0.0087* (0.0038)	−0.0003 (0.0006)	0.0084* (0.0037)
Unemploy	−0.0063** (0.0024)	0.0003 (0.0004)	−0.0060* (0.0024)	−0.0050* (0.0022)	0.0002 (0.0003)	−0.0045* (0.0021)	−0.0048* (0.0023)	0.0002 (0.0003)	−0.0046* (0.0022)
$n+\delta+g$	−0.0241*** (0.0052)	0.0012 (0.0015)	−0.0229*** (0.0050)	−0.0256*** (0.0054)	0.0011 (0.0018)	−0.0245*** (0.0052)	−0.0233*** (0.0053)	0.0008 (0.0014)	−0.0225*** (0.0054)
City%	0.0079* (0.0053)	−0.0004 (0.0006)	0.0075* (0.0050)	0.0020* (0.0023)	−0.0001 (0.0002)	0.0019* (0.0022)	0.0051* (0.0024)	−0.0002 (0.0003)	0.0049* (0.0023)
Service%	0.0189* (0.0105)	−0.0009 (0.0014)	0.0179* (0.0100)	0.0073* (0.0093)	−0.0003 (0.0008)	0.0069* (0.0089)	0.0009 (0.0097)	−0.0001 (0.0006)	0.0009 (0.0094)
EastPol	0.0033 (0.0056)	−0.0001 (0.0005)	0.0032 (0.0054)	−0.0048 (0.0049)	0.0002 (0.0005)	−0.0046 (0.0047)	−0.0052 (0.0043)	0.0002 (0.0004)	−0.0050 (0.0041)

Notes: Standard errors in parenthesis. *q < 0.1 denotes significance at 10% level. **q < 0.05 denotes significance at 5% level. ***q < 0.01 denotes significance at 1% level.

Source: Author's own elaboration.

Table 7. Results of SDEM and SLX models (weight matrix, k- nearest neighbour, with *k*=7)

Dep. variable: growth	SDEM model			SLX model		
	1	2	3	4	5	6
Lambda(λ)	−0.2122** (0.0822)	−0.2023* (0.0821)	−0.2132** (0.0822)			
$GDPpc_{t-1}$	−0.0134* (0.0070)	−0.0104 (0.0078)	−0.0105 (0.0078)	−0.0045 (0.0056)	−0.0064 (0.0058)	−0.0051 (0.0061)
Agri	0.0041 (0.0027)			0.0016 (0.0020)		
Fund		0.0125** (0.0046)			0.0060* (0.0030)	
Agrifund			0.0133** (0.0047)			0.0090* (0.0038)
Invest	0.0090** (0.0034)	0.0081* (0.0035)	0.0079* (0.0035)	0.0107*** (0.0030)	0.0095** (0.0031)	0.0097** (0.0031)
Unemploy	−0.0062** (0.0024)	−0.0049* (0.0024)	−0.0047* (0.0024)	−0.0058** (0.0021)	−0.0060** (0.0020)	−0.0056** (0.0020)
$n+\delta+g$	−0.0249*** (0.0053)	−0.0261*** (0.0053)	−0.0240*** (0.0053)	−0.0294*** (0.0048)	−0.0305*** (0.0047)	−0.0284*** (0.0047)
City%	0.0077 (0.0053)	0.0012 (0.0023)	0.0044 (0.0023)	0.0007 (0.0036)	−0.0003 (0.0017)	0.0101 (0.0081)

cont Table 7

Dep. variable: growth	SDEM model			SLX model		
	1	2	3	4	5	6
Service%	0.0196 (0.0100)	0.0074 (0.0097)	0.0011 (0.0101)	0.0233** (0.0081)	0.0124 (0.0079)	0.0087 (0.0021)
EastPol	0.0025 (0.0054)	−0.0055 (0.0047)	−0.0061 (0.0044)	−0.0053* (0.0029)	−0.0085** (0.0027)	−0.0087*** (0.0021)
$W \times GDPpc_{t-1}$	−0.0870*** (0.0156)	−0.0597*** (0.0141)	−0.0521** (0.0181)	−0.0048 (0.0175)	−0.0057 (0.0172)	−0.0011 (0.0172)
$W \times Agri\%$	0.0087 (0.0085)			0.0032 (0.0051)		
$W \times Fund\%$		0.0434** (0.0138)			0.0202* (0.0102)	
$W \times Agrifund\%$			0.0536*** (0.0157)			0.0143 (0.0117)
$W \times Invest\%$	−0.0157* (0.0080)	−0.0205* (0.0082)	−0.0199* (0.0081)	−0.0067 (0.0093)	−0.0108 (0.0095)	−0.0090 (0.0093)
$W \times Unemploy$	−0.0071 (0.0044)	−0.0108* (0.0045)	−0.0116** (0.0045)	0.0072 (0.0060)	0.0035 (0.0062)	0.0026 (0.0062)
$W \times n+\delta+g$	0.0793*** (0.0083)	0.0789*** (0.0083)	0.0773*** (0.0083)	0.0084 (0.0122)	0.0087 (0.0122)	0.0095 (0.0125)
$W \times City\%$	0.0385*** (0.0146)	0.0208*** (0.0050)	0.0338*** (0.0058)	0.0073 (0.0098)	0.0013 (0.0051)	0.0059 (0.0064)
$W \times Service\%$	−0.0589* (0.0272)	−0.0945** (0.0302)	−0.0970* (0.0295)	0.0191 (0.0237)	−0.0011 (0.0252)	−0.0023 (0.0264)
$W \times EastPol$	0.0011 (0.0093)	−0.0154 (0.0098)	−0.0052 (0.00089)	−0.0015 (0.0038)	−0.0064 (0.0067)	−0.0029 (0.0063)
Observations	1022	1022	1022	1022	1022	1022
N R²	73 0.39	73 0.40	73 0.40	73 0.37	73 0.37	73 0.37
F-statistic Log lik	– –	– –	– –	46.08 (0.0000) –	46.05 (0.0000) –	46.05 (0.0000) –

Notes: Standard errors in parenthesis. *q < 0.1 denotes significance at 10% level. **q < 0.05 denotes significance at 5% level. ***q < 0.01 denotes significance at 1% level.

Source: Author's own elaboration.

To verify the existence of local spillover effects with a new set of explanatory variables, the SDEM and SLX specifications are again applied (see Table 7). In the case of the SDEM model, the covariates (*Fund*) and (*Agrifund*) are positive and significant, confirming the positive effect of this funding on growth. Additionally, the spatial components (θWX) of these covariates are also positive and significant, suggesting the existence of a local spillover effect where funding allocated in a given region impacts positively on border areas. Furthermore, estimates based on the SLX model also confirm the positive effect of structural funds and the coupled value of both policies on growth. However, only the spatial lag of the structural funds variable $W \times Fund$) is positive and significant, confirming the local spillover effect. Moreover, both the SDEM and SLX specifications indicate that CAP subsidies do not impact growth or provoke spillover effects of actions supported by the CAP policy.[10]

Discussion and conclusion

This study employs spatial panel methods to investigate the spatial effects of Common Agricultural Policy (CAP) subsidies and Cohesion Policy (CP) funds across Polish NUTS 3 subregions. The study provides empirical evidence of local spillover effects of EU policies, showing that structural funds, along with their coupled

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[10] The results' sensitivity was also tested using cross-sectional data. The findings from the empirical models confirm the results obtained through panel data analysis.

value with CAP subsidies, positively impact growth in border areas. However, the study does not detect any global spillover effects, indicating that investments supported by CP in a given region do not affect all areas covered in the analysis. These results are consistent with the findings of **Fiaschi et al.** [**2017**], which confirmed the presence of externalities of structural funds in 175 regions of 12 EU countries between 1989 and 2006.

The results suggest that EU support through Common Agricultural Policy (CAP) subsidies and structural funds has a positive impact on subregional growth. These findings confirm a previous study that examined the effectiveness of CP in Poland at the NUTS 2 level, which found a positive relationship between structural funds and growth in the 2004–2016 period [**Piętak, 2021**]. Similarly, in Spain, which was the biggest beneficiary country in 1989–2006, empirical studies have shown the positive effects of structural funds on regional growth [**Pérez et al., 2009**; **Villaverde, Maza, 2010**].

The positive impact of structural funds in Poland may be based on the size of this support relative to regional GDP. Transfers that are either too low or too high do not yield optimal results [**Becker et al., 2012**; **Cerqua, Pellegrini, 2018**]. **Becker et al.** [**2012**] estimated the threshold to be 1.8% for EU-15 regions in the 1994–1999 period, beyond which the funds have no significant effect. **Fiaschi et al.** [**2017**] estimated the threshold to be 3.0% for 175 Objective 1 regions of EU-12 during the 1991–2008 period. However, in the case of Polish NUTS 2 regions, the threshold beyond which the effectiveness of funds decreases is 0.9% of the regional GDP (see Appendix 4).

Regarding the role of structural funds in reducing regional disparities, it can be observed that the largest beneficiaries are not only located in poorer eastern Poland but also in more developed Polish cities such as Wrocław, Warszawa or Łódź (see Appendix A). Also, in the first period of Poland's membership in 2004–2006, more funds were directed to economically stronger regions [**Churski, 2008**]. To assess whether the allocation of Cohesion Policy funds has been egalitarian, a linear regression was applied where the dependent variable was the value of structural funds per capita allocated to subregions from 2007 through 2020, and the independent variable was the GDP per capita in 2007. The value of the parameter b (– 0.03) was negative, but statistically insignificant, which does not confirm the egalitarian distribution of funds. As stressed by **Barca** [**2009**] and **Pieńkowski and Berkowitz** [**2015**], the geographical concentration of funds can lead to positive spatial spillover effects. However, in the case of Poland, the high support for relatively developed areas may actually enhance the existing divergence rather than reduce the regional gap.

The outcomes of the study suggest the existence of a spillover effect from the funds, which carries important implications for policymakers. First, the geographical concentration of funds should be encouraged to take advantage of positive spatial externalities. Allocating funds to poorer areas not only serves as an incentive for further development but also creates favourable conditions for neighbouring regions. Second, the funds should be focused on a limited number of priorities to avoid diluting their potential positive impact. The study's findings suggest that, in some cases, the overall impact of the funds is stronger and more statistically significant than the impact of EU support considered in isolation. Third, investments co-financed by the funds should promote the development of education and innovation, which can serve as a solid foundation for endogenous regional growth. While physical infrastructure remains important for development, Poland is now at a different stage of economic advancement, and other factors – such as education s– whould be prioritised.

Finally, since 2004, Poland has consistently recorded economic growth rates higher than the EU average, indicating strong convergence with other EU economies. According to Eurostat data, in 2020, Poland's GDP per capita (purchasing power standard) reached 76% of the EU average. Three NUTS 2 regions – Warszawski Stołeczny (167%), Dolnośląskie (84%), and Wielkopolskie (83%) – have exceeded the threshold of 75% of the EU average. In the next financial perspective, after 2027, Poland will transition from being the largest beneficiary of EU policies to becoming a net contributor. In this context, the central government should foster sustainable economic growth by investing in national programmes with a regional dimension.

Further research could assess the transmission channels through which spatial effects impact regional growth in neighbouring areas. The sample data could be expanded to include neighbouring countries with

which Poland maintains strong economic ties. Additionally, structural support provided by CP covers only part of total investment costs, with the remainder financed by regional or local governments. It would be useful to evaluate whether CP funds crowd in or crowd out regional public investment. Although recent econometric studies do not provide clear evidence, some suggest that structural funds may reduce domestic public investment [**González Alegre, 2010**; **García Nicolás and Cantos, 2018**]. Empirical outcomes may vary depending on the model's specification. For example, **Backer et al.** [**2010**] show that the effect of CP is positive in the case of GDP per capita growth, but the specification for assessing the relationship between funds and employment provides insignificant results. Therefore, it is necessary to assess the sensitivity of the results across different dependent variables, particularly in the case of the largest beneficiary country.

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Appendix

## Appendix A: Allocation of Structural Funds and CAP Subsidies in Poland

Table A1. Cohesion Policy and Common Agricultural Policy (CAP) in Poland

	Cohesion Policy			Common Agricultural Policy		
	Total value (EUR billion)	Per capita (EUR)	Percentage of CP	Total value (EUR billion)	Per capita (EUR)	Percentage of CAP
2004–2006	12.8	105.9	3.5%	5.8	51.3	4.3
2007–2013	67.2	251.7	19%	26.5	99.4	7.2
2014–2020	77.6	291.4	22%	24.0	105.2	7.6

Notes: Total value covers the financial resources of structural funds and the Cohesion Fund. The amount of Common Agricultural Policy funding covers the subsidies of the 1st and 2nd pillars. The values per capita express the annual amount of funds per head of population.

Source: Author's own elaboration.

Figure A1. Distribution of structural funds and CAP subsidies in NUTS 3 subregions, annual average value (EUR per capita)
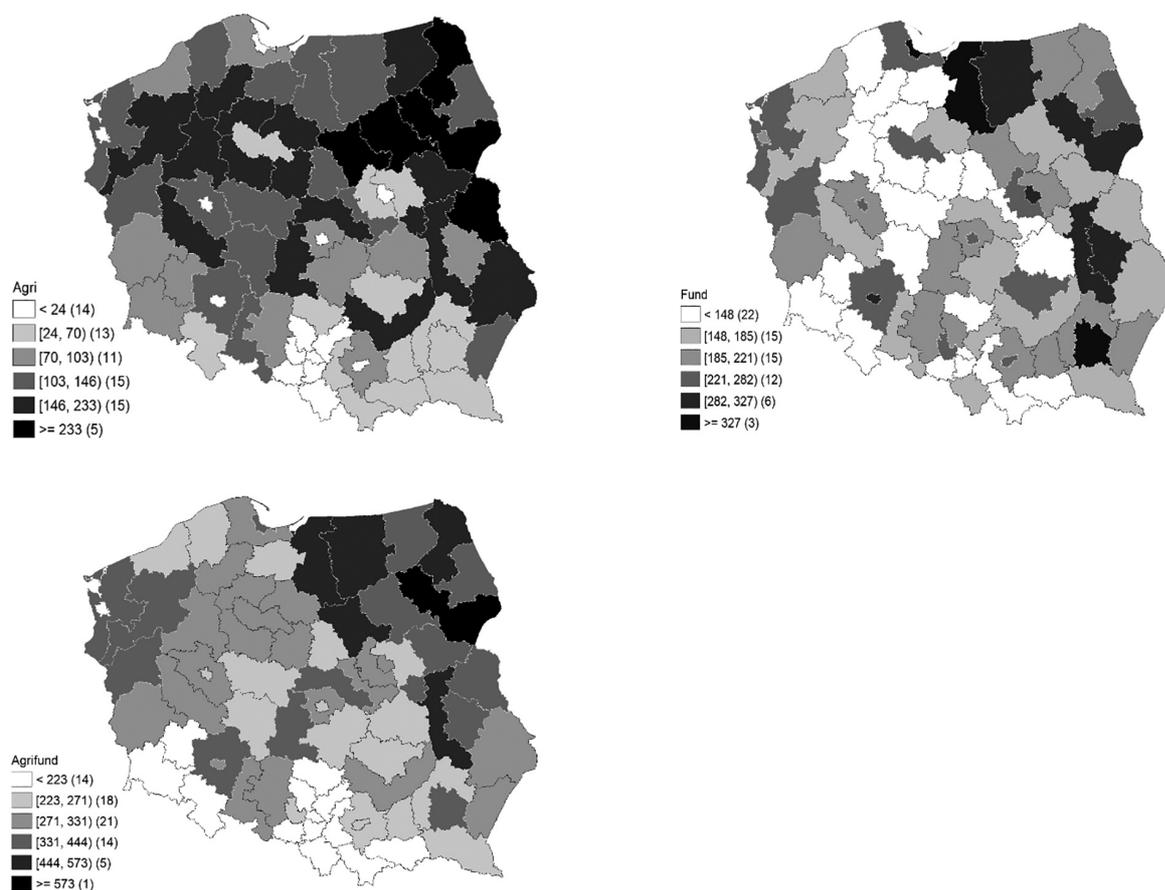
Source: Author's own elaboration.

Appendix B: Theoretical Model of Regional Growth with Spatial Externalities

The production function of the model is written as follows:

$$Y_{it} = A_{it} K_{it}^{\theta k} H_{it}^{\theta h} L_{it}^{1-\theta k-\theta h} \tag{A.1}$$

where Y_{it} is the output flow, K_{it} is the stock of physical capital, H_{it} is human capital, L_{it} is the labour force and A_{it} is the level of exogenous technology in each region. A positive and diminishing marginal product characterises the function for each input and constant returns to scale.

The production function in intensive form is:

$$y_{it} = A_{it} k_{it}^{\theta k} h_{it}^{\theta h} \tag{A.2}$$

where $y_{it} = Y_{it}/L_{it}, k_{it} = Y_{it}/K_{it}, h_{it} = H_{it}/L_{it}$ are units per unit of labour and θ_k and θ_h are marginal internal returns to physical and human capital respectively.

The level of technology A_{it} in each region depends on the technological level in neighbouring areas, which in turn are conditioned by the accumulation of physical and human capital

$$A_{it} = \Delta_t \left(k_{\rho it}^{\theta k} h_{\rho it}^{\theta h} \right)^{\gamma} \tag{A.3}$$

where Δ_t is the level of exogenous technology identical for all economies, $k_{\rho it}$ and $h_{\rho it}$, γ measures the externalities across economies. According to Equation A.3, the increase of physical and human capital in neighbouring regions ($k_{\rho it}$, $h_{\rho it}$) causes the rise of technology in area i by $\gamma\theta k$ and $\gamma\theta h$ percent respectively.

Substituting Equations A.3 in Equation A.2, we obtain the formula of labour productivity in region i

$$y_{it} = \Delta_t k_{it}^{\theta k} h_{it}^{\theta h} \left(k_{\rho it}^{\theta k} h_{\rho it}^{\theta h} \right)^{\gamma} \tag{A.4}$$

From Equation A.4 it can be seen that the labour productivity of region i depends on the stock of physical and human capital, but also on the accumulation of theses capitals in border areas.

Appendix C: Descriptive Statistics of Variables

Table C1. The set of regressors entered in the econometric models

Variable	Marking	Description	Source of data
Economic growth	Growth	The logarithm of the annual growth rate of GDP per capita	Local Data Bank, Statistics Poland (GUS)
Gross domestic product per capita	GDPpc	The logarithm of the initial value of GDP per capita	Local Data Bank, Statistics Poland (GUS)
CAP subsidies	Agri	The logarithm of the annual average value of CAP subsidies per capita	Agency for Restructuring and Modernisation of Agriculture (ARMA)
Structural funds	Fund	The logarithm of the annual average value of structural funds per capita	Ministry of Development Funds and Regional Policy
Structural funds and CAP subsidies	Agrifund	The logarithm of the coupled value of structural funds and CAP subsidies per capita	Ministry of Development Funds and Regional Policy; Agency for Restructuring and Modernisation of Agriculture (ARMA)
Investment	Invest	The logarithm of the investment outlays in enterprises is calculated as a percentage of GDP.	Local Data Bank, Statistics Poland (GUS)
Unemployment	Unemploy	The logarithm of the share of the labour force without work	Local Data Bank, Statistics Poland (GUS)
Population growth rate	$n+\delta+g$	The logarithm of the combined growth rate of population, capital depreciation and exogenous technological progress	Local Data Bank, Statistics Poland (GUS)
Population density	Dens	The logarithm of the number of people per square kilometre	Local Data Bank, Statistics Poland (GUS)
Big cities	Bigcity	The dummy variable, if a city of 250,000 people is located in a subregion, the value is 1, otherwise 0.	Statistics Poland (GUS)
Eastern Poland	EastPol	The dummy variable, if a subregion is located in NUTS 2 regions of eastern Poland, the value is 1, otherwise 0.	Statistics Poland (GUS)

Source: Author's own elaboration.

Table C2. Descriptive statistics

Variable	Mean	Median	S.D.	Min.	Max.
Const	0.034	0.036	0.001	−0.123	0.169
GDPpc	7692.6	6685.7	103.8	4123.2	29997.3
Agri	100.1	93.6	2.23	0.20	300.6
Fund	191.4	171.3	1.98	104.3	403.0
Agrifund	291.6	280.8	2.72	128.1	591.3
Invest	650.0	531.1	12.3	149.6	3020.9
Unemploy	11.7	11.4	0.19	1.1	29.0
$n+\delta+g$	0.049	0.048	0.0002	0.0079	0.119
Dens	360.4	103.0	21.8	41.0	3462.0

Source: Author's own elaboration.

Table C3. Spatial correlation of regressors, Moran's I statistic

Variables (in logs)	Moran's I	Marginal probability
Const	0.096	0.076
GDPpc	0.251	0.002
Agri	0.130	0.043
Fund	0.219	0.002

cont Table C3

| Variables (in logs)	Moran's I	Marginal probability
Agrifund	0.504	0.001
Invest	0.273	0.001
Unemploy	0.394	0.001
n + δ + g	0.273	0.003
Dens	0.244	0.002

Notes: The formula of global Moran's I [**Moran 1950**] statistic is $I = \dfrac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \times \dfrac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$, where w_{ij} is the element of

the spatial contiguity matrix, W, such that $w_{ij} = 1$ if regions *i* and *j* are neighbours and $w_{ij} = 0$ otherwise, x_i is the value of the variable under consideration in region *i* at time *t*, and *n* is the number of regions under investigation. A randomisation approach is applied to obtain a spatially random reference distribution to estimate statistical significance (999 permutations).

Source: Author's own elaboration.

Appendix D: Dose-Response Function

Figure D1. Estimated average total effect on GDP growth of structural funds in Poland, 2007–2020 (NUTS 2 regions)
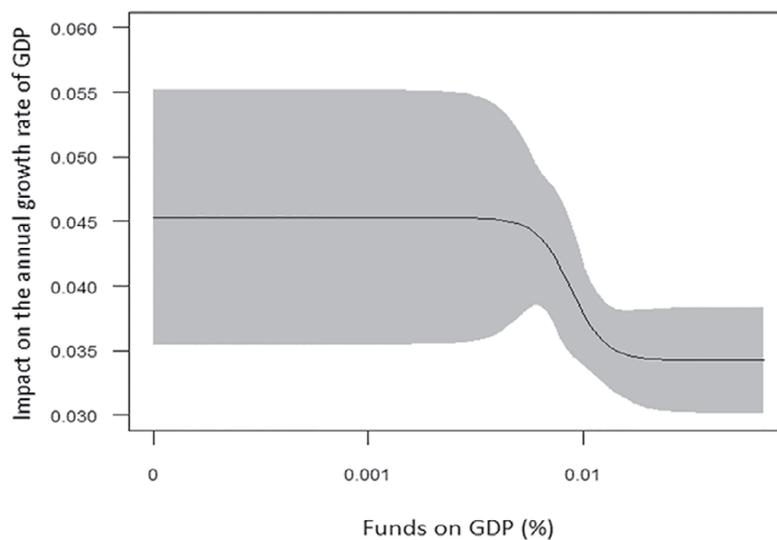
Notes: Grey area represents 95% confidence interval.

Source: Author's own elaboration.