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The Impact of EU Funds on Regional Economic Growth of the Czech Republic*

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Abstract

This research paper aims to estimate the impact of European Structural and Investment Funds (ESIF) on economic growth of the Czech Republic during the period 2004-2015 using panel data regression techniques. ESIF are instruments of European economic and social cohesion policies. The primary goal of these policies is to foster economic growth and convergence among the member states of the European Union through the reallocation of financial resources from ESIF. During 2004-2015, the Czech Republic was involved in three programming periods in which projects of an approximate value of 939 billion CZK were supported and implemented. The contribution from ESIF was approximately 757 billion CZK while 182 billion CZK were allocated from national resources. Besides the standard panel data regression techniques like pooled OLS or FE, a spatial panel data econometric method is employed. Evidence of this research shows a positive relationship between ESIF and economic growth of NUTS3 regions of the Czech Republic. Furthermore, the results also suggest economic convergence among NUTS3 regions of the Czech Republic.

1. Introduction

European Structural and Investment Funds (ESIF) are instruments of European economic and social cohesion policies with the aim to support the economic growth of the European member states and promote economic convergence among them. ESIF are of high importance for less-developed regions since these funds should help in the catching-up process and in reducing disparities among them. Various analyses and assessments attempting to explain the main drivers of economic growth and economic convergence have been long time the subject of a wide range of research. With the

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onset of the European economic and social policies funded through EU funds, research has also begun to focus on the impacts of EU funds and their implications for economic growth and development. Examples of such studies can be Fuente et al. (1995), Cappelen et al. (2003), Dall'erba and Le Galo (2008), Mohl and Hagen (2010), Bouayad-Agha et al. (2013), Maynou et al. (2014), Rodríguez-Pose and Garcilazo (2015), Fratesi and Perucca (2014), and others. Even though the list of publications is extensive, the quantitative evaluations of the impacts of ESIF on economic growth of the Czech Republic are scarce. The only exceptions are Kejak and Vávra (1999) and the Ministry of Regional Development (2006), who performed the ex-ante evaluation of the impacts of the programming periods 2000-2006 and 2007-2013 respectively. There can be found no ex-post assessments so far. There is a great need of analytical studies and empirical results in the context of the Czech Republic to make informed policy decisions. Moreover, the ex post evaluations will play a crucial role in the setting of the multiannual financial framework after year 2020.

Therefore, this research paper aims to fill this gap by estimating the impact of ESIF on regional economic growth of the Czech Republic during the period 2004-2015. This research extends the current literature in several aspects. First, it provides a single-country result focused on the Czech Republic, which have not been done before. Such an approach is desirable since the estimations provide us with a particular average effect on the economy of the Czech Republic. Second, it employs a unique and the most precise data set covering NUTS3 regions of the Czech Republic over the period 2004-2015 which has been provided from the internal information systems of the Ministry of Regional Development of the Czech Republic. Finally, it offers a first quantitative assessment of the impacts of ESIF in the Czech Republic using the spatial-panel data econometric techniques. The spatial-panel data econometric techniques have been chosen since the results of the regression model without spatial dimension might be biased due to the presence of regional spillover effects (as highlighted by early works on the economic geography – such as Krugman, 1991). As pointed by Dall'erbe and Le Gallo (2007), when not accounting for spatial effects, regions are modelled as isolated entities. However, this might not be the case since richer and poorer regions tend to create clubs. As documented by Venables and Gasiorek (1999), EU funds produce externalities and financing of transportation structures fosters agglomeration forces in regions financing of transportation structures fosters agglomeration forces in regions. Moreover, Anselin (1988) suggests that positive spatial dependence is likely to occur among regional observations.

The results of this research indicate the positive impact of ESIF on economic growth of regions of the Czech Republic. The estimations suggest that without the financial aid from ESIF, the economic growth of the Czech economy would had been lower by approximately 0.91 p.p. to 1.12 p.p. on average during the period 2005-2015 based on the data sample considered.

The rest of the paper is organised as follows. Section 2 provides a literature review. Section 3 focuses on ESIF in the Czech Republic. Section 4 outlines the methodology. Section 5 discusses the estimation results and section 6 concludes.

2. Literature Review

There are many research papers devoted to the evaluation of EU funds. The main difference between these studies resides in the geographical scope, the modifications of the regression models to capture various phenomena (such as spillover effects), and the employed estimation procedure. A positive effect of EU funds on economic development is recognised in most of studies.

The pioneering studies and analyses evaluating the impact of EU funds come from the 1990s. The very first research papers investigated the questions related to ESIF using the basic econometric techniques applied to particular regions. For example, Gaspar and Pereira (1992) and Fuente et al. (1995) examined the impacts of the structural funds (hereinafter SF) and cohesion policy in Portugal and Spain respectively. The first studies were followed by new ones that applied very similar models to new data sets covering additional programming periods of the financial aid from the EU. Such examples can be Cappelen et al. (2003) who investigated the impacts during the period 1980-1997, or Eggert et al. (2007) who focused on the period 1994-2005. The simple evaluation studies were then completed with publications aimed at analysing the effectiveness of spending. Ederveen et al. (2006) documented that SF are ineffective on average, while Tomova et al. (2013) identified ESIF to be effective, and that the level of effectiveness is conditional on other factors such as national fiscal policies. Other studies, such as Boldrin and Canova (2001) or Dall'erba and Le Galo (2008) focused on economic convergence caused by EU funds. While the first study found a limited impact, the second study concluded with a neutral impact of EU funds.

Even though the results of some research papers confirmed the positive impact of EU funds on economic growth and economic convergence, the results were not seen robust because of their inability to capture spatial dimension of the impacts of EU funds. Therefore, new econometric approaches have been applied. Ramajo et al. (2008) or Moll and Hagen (2010) employed the spatial weight matrix to capture interregional growth dynamics. Ramajo et al. (2008) applied a spatial Durbin model whereas Moll and Hagen (2010) augmented a baseline model with a spatially weighted dependent variable. Lesage and Fischer (2008) and De Dominicis (2014) applied the spatial Durbin model, while Fratesi and Perucca (2014) augmented the standard errors of the estimates for spatial autocorrelation. These studies showed that EU funds have positive effect on economic growth; however, after controlling for the spatial dimension, the effect of EU funds is smaller. The impacts of EU funds have been also investigated using modern non-parametric econometric techniques, such as regression discontinuity design or propensity score matching. For example, Becker et al. (2010) or Pellegrini et al. (2013) employ regression discontinuity design to show the implications of the threshold for Objective 1 eligibility and its impact on economic growth. However, these modern methods are irrelevant in our case, since they require the construction of treatment and treated groups. The common approach is to select these groups based on Objective 1 eligibility. Since all regions of the Czech Republic, except for Prague, are Objective 1 regions and their economic performance is very similar, there is no possibility to construct two different groups of regions. Moreover, the small data sample would pose another difficulty.

Regarding the geographical scope, most of the studies focus on large geographic units and thus provide an average impact of EU funds on economic development. For example, Tomova et al. (2013) or Rodríguez-Pose and Garcilazo (2015) focused on all member states of the European union while Pellegrini et al. (2013) investigated the impacts of EU funds in the euro area. On the contrary, there are a few studies devoted only to certain regions, such as Soukiazis and Antunes (2006) who focused on Portugal. Such studies are important as well because they show the heterogeneity of the impacts among different countries. There is also a stream of research that studies the effects of the existing macroeconomic conditions and institutional or political environment on the effectiveness of the EU funding (Guillaumont and Chauvert 2001, Puigcerver-Peñalver 2007, Katsaitis and Doulos 2009, or Becker et al. 2010). Finally, there are studies (such as Bouayad-Agha et al. 2013) that document different impacts of various programmes (for example Objective 1 vs. Objective 2 programme) of EU funds on GDP. Beside the studies focusing on the impacts of EU funds on economies as a whole, there are also research papers devoted to the investigation of the impacts on a sectoral level (for example Christodoulakis and Kalyvitis 1998).

Apart from the empirical econometric analyses, structural macroeconomic models have been employed to evaluate the impacts of EU funds on various variables, such as GDP, labour productivity, or unemployment. The pioneering studies, such as Bradley and Untiedt (2006) or Bradley (2012) employed the model HERMIN based on national accounting. The model HERMIN was also used in the Czech Republic. Kejak and Vávra (1999) modified the HERMIN model for the Czech conditions to evaluate the possible impacts of the financial resources from EU funds during the 2000-2006 programming period. The Ministry of Regional Development (2006) used the model for the ex-ante evaluation of the macroeconomic impacts of the 2007-2013 programming period.

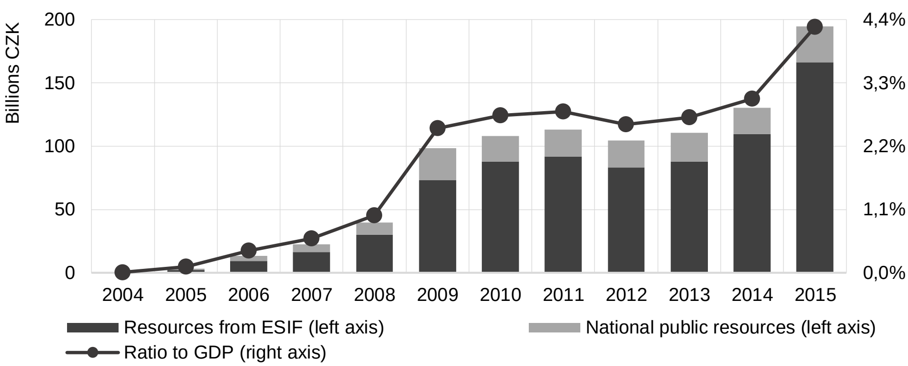
The simple model HERMIN has been replaced with various CGE and DSGE structural macroeconomic models in the later stage. The most active in the field of application of structural macroeconomic models for the evaluation of EU funds is the European Commission with its QUEST model. The QUEST model is a structural macroeconomic model in the New-Keynesian tradition with various frictions in goods, labour and financial markets. The model was first applied to the evaluation of EU funds by Varga and in't Veld (2011) to analyse the impact of Cohesion policy expenditures during the programming period 2000-2006. Varga and in't Veld (2010) employed the same model for the ex-ante evaluation of the 2007-13 programming period. The last application of the QUEST model was done by Monfort et al. (2017). Since the QUEST model does not capture the regional division of countries, the European Commission constructed the regional structural macroeconomic CGE model RHOMOLO. This model was employed, for example, by fort Monfort et al. (2016) to measure the impacts of cohesion policy in the programming period 2007-2013.

3. ESIF in the Czech Republic

The Czech Republic was involved in three programming periods of the financial aid from ESIF during the period 2004-2015. Since the Czech Republic joined the European Union in 2004, the first programming period was limited to years 2004 to 2006. The second programming period lasted seven years (2007-2013). The third programming period launched in 2014 is expected to end in 2020. For the first two programming periods, the Czech Republic defined its priorities in line with the European Union in the National Strategic Reference Framework. The main determined priorities were, for example, the support of less-developed regions, convergence between regions and the support for employment policies. The Czech Republic has developed a Partnership Agreement for the third programming period. This agreement contains objectives in line with the strategy Europe 2020 and the course of support from ESIF to achieve effective allocation of financial resources.

Overall, during the three programming periods between 2004 and 2015, the Czech Republic received approximately 757 billion CZK from the EU with the amount co-financed from the national public resources representing 182 billion CZK. Therefore, projects for a total of approximately 939 billion CZK were implemented during the period 2004-2015.[1] Figure 1 describes the evolution of the financial resources from ESIF and national public sources for the period 2004 to 2015. An interesting fact is that cumulatively only 19.5 % of the total financial resources spent on the projects during the period 2004-2015 were financed from the national public sources. This fact indicates the obvious advantage of European projects for domestic agents (municipalities, public organizations, etc.) who participate on the co-financing of the projects by a relatively low share.

Figure 1 Allocation of ESIF and National Public Resources



Source: Czech Statistical Office, Ministry of Regional Development, own calculations.

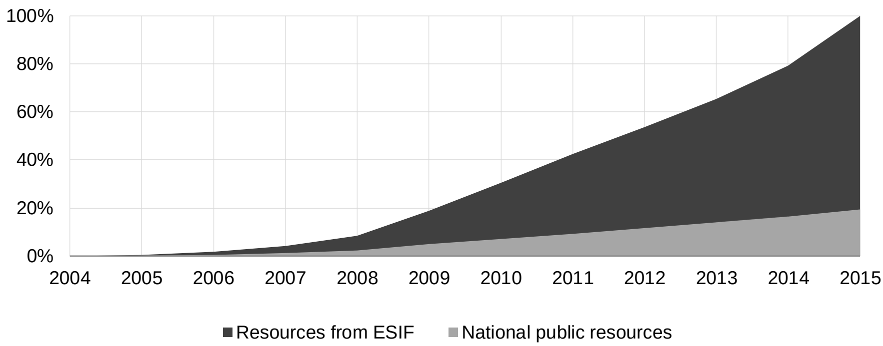
Figure 1 also captures the dynamics of drawing of funds during the three mentioned programming periods. The first programming period is characterised by a relatively low amount of financial resources due to the accession of the Czech Republic to the European Union in 2004. The sharp increase in 2009 is caused by the first major wave of the completed short-term projects in the second programming period. The

[1] The total amount is calculated as a sum of the financial resources from ESIF and the national public sources for all three programming periods covering years 2004-2015. Private resources used as co-financing are not included due to data unavailability. In addition, funding from the Rural Development Program (which is not covered by the National Strategic Reference Framework in 2007-2013) is included.

same reasoning applies for the sharp increase in 2015. The importance of the projects financed from ESIF and national resources is reflected by their ratio to GDP. The share of the sum of ESIF and national resources to GDP ranged from 0.01 % to 4.27 % during the period 2004 and 2015. The annual average of this ratio reached 1.9 % of GDP.

The time profile of drawing of ESIF is shown in Figure 2. As Figure 2 suggests, drawing of the financial resources from ESIF was uneven over time with the obvious rising tendencies at the end of the programming periods. The reason behind such a dynamic can be attributed to the long-term large-scale projects. Another reason explaining the accelerating rate of drawing at the end of the programming periods can be the increased activity (and a change of strategy) of the managing authorities often due to the concerns about the incomplete depletion of the financial resources from ESIF. A significant contribution to the increased activity around the ending dates of the programming periods was the so-called "n+2 rule" which allows to obtain the financial resources from ESIF even two years after the end of the respective programming period. The increase in the last two years of the monitored period 2004-2015 was caused also by the start of the programming period 2014-2020. However, the amount of the financial resources related to the new programming period was not enormous (approximately 1.2 billion CZK).

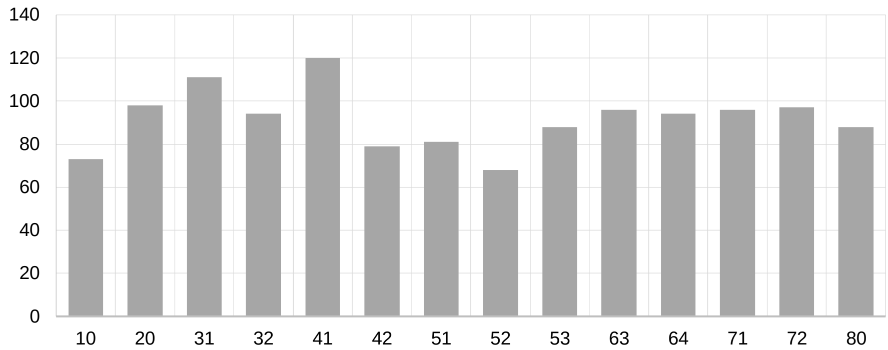
Figure 2 Cumulative Drawing of ESIF and National Public Resources



Source: Ministry of Regional Development, own calculations.

Figure 3 captures the distribution of the sum of ESIF and national public resources per capita spent on the projects during the period 2004-2015. As can be seen, the largest proportion of the projects was implemented in the region CZ041 (Karlovarský kraj) followed by the region CZ031 (Jihočeský kraj). On contrary, the projects for the lowest amount of financial resources per capita were implemented in regions CZ052 (Královéhradecký kraj) and CZ010 (Prague). The relation between average real GDP growth per capita and the average of the sum of ESIF and the national public resources per capita during the period 2004-2015 is illustrated by Figure 4. The highest average value of the sum of the ESIF and the national public resources per capita attained the region CZ041 (Karlovarský kraj). At the same time, this region achieved the lowest value of real GDP growth among all regions. This particular region demonstrates that the most lagging region obtained the highest financial aid from ESIF. On contrary, the financial support from ESIF attained the lowest value per capita in the region CZ052 (Královéhradecký kraj).

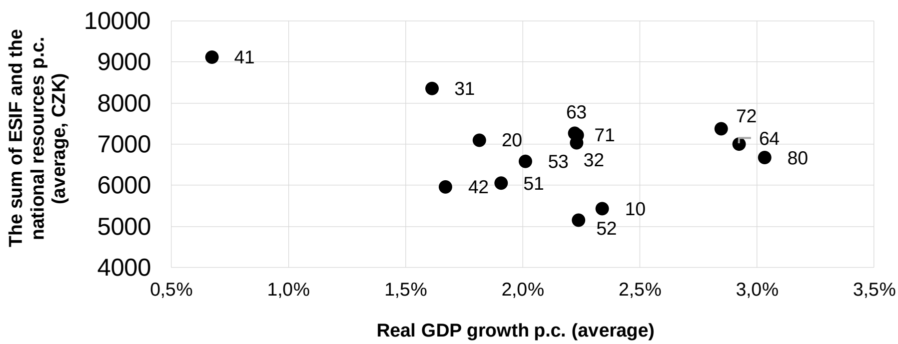
Figure 3 The Division of the Sum of ESIF and National Public Resources per Capita in Regions of the Czech Republic over the Period 2004-2015, thousands CZK



Notes: 10 Prague, 20 Středočeský kraj, 31 Jihočeský kraj, 32 Plzeňský kraj, 41 Karlovarský kraj, 42 Ústecký kraj, 51 Liberecký kraj, 52 Královéhradecký kraj, 53 Pardubický kraj, 63 kraj Vysočina, 64 Jihomoravský kraj, 71 Olomoucký kraj, 72 Zlínský kraj, 80 Moravskoslezský kraj.

Source: Ministry of Regional Development, own calculations.

Figure 4 The Relationship between Average Real GDP Growth per Capita and Average of the Sum of ESIF and the National Public Resources per Capita during 2004-2015



Notes: 10 Prague, 20 Středočeský kraj, 31 Jihočeský kraj, 32 Plzeňský kraj, 41 Karlovarský kraj, 42 Ústecký kraj, 51 Liberecký kraj, 52 Královéhradecký kraj, 53 Pardubický kraj, 63 kraj Vysočina, 64 Jihomoravský kraj, 71 Olomoucký kraj, 72 Zlínský kraj, 80 Moravskoslezský kraj.
Source: Czech Statistical Office, Ministry of Regional Development, own calculations.

4. Methodology and Data

4.1 Econometric Specification

To evaluate the impact of ESIF on regional economic growth of the Czech Republic we closely follow the empirical approach of Rodríguez-Pose and Novak (2013) who construct a neo-classical empirical model. We measure the impact of ESIF on economic growth of regions while controlling for the starting growth position of regions and other factors. The explanatory variables are specified in lags due to potential endogeneity which might bias the estimates of the parameters, and therefore negatively affect the results of the estimation. The baseline model to be estimated takes the following form

$$\ln(y_{i,t}/y_{i,t-1}) = \beta_0 + \beta_1 y_{i,t-1} + \beta_2 innov_{i,t-1} + \beta_3 ESIF_{i,t-1} + \beta_4 infr_{i,t-1} + \beta_5 educ_{i,t-1} + \mu_i + u_{i,t} \quad (1)$$

where the subscript $i = 1, \ldots, 14$ denotes the region and the subscript $t = 1, \ldots, 12$ denotes the time period, $y_{i,t}$ is GDP per capita, $innov_{i,t}$ is private investment on R&D activities per capita, $ESIF_{i,t}$ represents expenditures on ESIF per capita, $infr_{i,t}$ characterises the level of infrastructure represented by the infrastructure index, and $educ_{i,t}$ is an indicator of a quality of human capital. The reasoning to include individual variables is following.

Real GDP per capita (y): A standard measure of regional economic performance. Its lagged value captures the conditional convergence and the starting growth position.

Research and development ($innov$): Innovation has long been recognized as a key factor for sustainable economic growth. Křístková (2012, 2013) finds a positive impact of R&D activities on economic growth in the Czech Republic. Literature identifies several possible explanatory variables for R&D. Despite limited data availability at the regional level, private and public R&D expenditures, or number of patents data is nevertheless available. Since the patent activity in the Czech Republic is not so high and public R&D expenditures might serve different purposes than innovation activities, private R&D expenditures are seen as the most suitable candidate. Private R&D expenditures are expressed in per capita terms.

The level of infrastructure ($infr$): Several studies have confirmed the significant impact of infrastructure on economic growth (for example Aschauer 1989, Canning 1999, Demetriades and Mamuneas 2000, or Röller and Waverman 2001). Therefore, infrastructure development is seen as an important factor behind economic growth. Various studies use various proxies for infrastructure (such as motorways, railways, or tele-communications). To obtain a more complex and robust indicator of infrastructure development, the composite index of infrastructure as in Calderon and Serven (2004) is constructed.[2] The index captures three variables: the density of the road network per square km (V), the density of railway lines per square km (X) and the

[2] To test the robustness of the results, different specifications of the proxies are employed. However, the estimates of the ESIF coefficient do not change substantially over the different specifications. The results are available upon request.

installed power capacity per one thousand inhabitants (Z). The index is then expressed as

$$infr_{i,t} = 0.5 \ln(V_{i,t}) + 0.5 \ln(X_{i,t}) + 0.61 \ln(Z_{i,t}) \quad (2)$$

The quality of human capital ($educ$): Standard growth regressions account for human capital as one of the main drivers of economic growth (for example Oancea et al. (2017) find a positive relationship for the Czech Republic). The common approach is to use the share of population with tertiary education as a proxy variable.

Since the Czech Republic experienced during the investigated period the financial crisis that caused a significant drop in economic growth, suspicion about the presence of a structural break arises. Because the date of the structural break is known, the data sample is divided into two subsamples (2004-2008 and 2009-2015). The statistical significance of this break is investigated using the Chow test of a structural change. The statistical test confirms the presence of the structural break (18.483, p-value: 0.000) leading to a modification of the model (1) with the dummy variable sb_t controlling for the structural break.

$$\ln\left(y_{i,t}/y_{i,t-1}\right) = \beta_0 + \beta_1 y_{i,t-1} + \beta_2 innov_{i,t-1} + \beta_3 ESIF_{i,t-1} + \beta_4 infr_{i,t-1} + \beta_5 educ_{i,t-1} + \beta_6 sb_t + \mu_i + u_{i,t} \quad (3)$$

The results of the standard panel data regression methods (such as pooled OLS or fixed effects) might be biased due to spatial effects. There might be spillover effects among regions which could potentially explain the portion of the results achieved by standard panel regression methods. As pointed by Dall'erbe and Le Gallo (2007), when not accounting for spatial effects, regions are modelled as isolated entities. However, this might not be the case since richer and poorer regions tend to create clubs. Moreover, as documented by Venables and Gasiorek (1999), EU funds produce externalities and, for example, financing of transportation structures fosters agglomeration forces in regions. To account for the spillover effects, the spatial panel data regression methods in line with Elhorst (2009) or Mohl and Hagen (2010) are employed. The spatial panel data models rely on the weight matrix $\boldsymbol{W}$ that contains information about the interconnection between regions. The matrix $\boldsymbol{W}$ is square and it has fourteen rows (columns) that correspond to fourteen regions that constitute the Czech Republic. The diagonal elements of the matrix $\boldsymbol{W}$ are equal to zero (no "self-influence" is assumed) and the non-diagonal entries characterise the spatial dependence between the region j and k which is measured by geographical distance between the capitals of regions.[3] Following the studies mentioned above, we design the weight matrix $\boldsymbol{W}$ as the k-nearest neighbours weight matrix by setting $k = 3$. The elements of this matrix are defined as

[3] Because the capital of regions Prague and Středočeský kraj coincide, distance between these two regions is set arbitrarily to 30 km.

$$\boldsymbol{W}(k) = \begin{cases} w_{ij}(k) = 0 & if \quad i = j \\ w_{ij}(k) = 1/3 & if \quad d_{ij} \leq d_i(k) \\ w_{ij}(k) = 0 & if \quad d_{ij} > d_i(k) \end{cases} \tag{4}$$

where w_{ij} is an element of the weight matrix $\boldsymbol{W}$, $d_i(k)$ is the smallest distance between region i and j such that the region i has $k = 3$ neighbours, and d_{ij} is the distance between capitals of the region i and j.

There are several ways of how to include the spatial dimension into the model. One possibility is to create a spatially weighted dependent variable, the other one to integrate a spatially autocorrelated error term into the model. To identify the form of the spatial dependence, we run LM tests (LMERR and LMLAG). We also compute global Moran's I statistic. All statistical tests strongly favour the spatial dependence (p-values: 0.000) and suggest integrating both the spatially weighted dependent variable and the spatially autocorrelated error term.[4] However, after estimating the models, the coefficient on spatially autocorrelated error term turns out to be highly insignificant in most cases.[5]We also tried to fit the spatial Durbin model. However, all spatial coefficients were insignificant. Therefore, we resort to the spatial autoregressive model (SAR) as Mohl and Hagen (2010) and apply the Driscoll and Kraay (1998) method to correct standard errors for spatial dimension. The model takes the form

$$\begin{aligned} \ln\left(\frac{y_{i,t}}{y_{i,t-1}}\right) = \beta_0 + \rho \sum_{j=1}^{14} w_{ij} \ln\left(\frac{y_{i,t}}{y_{i,t-1}}\right) + \beta_1 y_{i,t-1} + \beta_2 innov_{i,t-1} \\ + \beta_3 ESIF_{i,t-1} + \beta_4 infr_{i,t-1} + \beta_5 educ_{i,t-1} + \beta_6 sb_t \\ + \mu_i + u_{it} \end{aligned} \tag{5}$$

where ρ is the spatial autoregressive coefficient. Since the model specified by equation (5) suffers from simultaneity due to the inclusion of the spatially weighted dependent terms, the quasi maximum likelihood approach described by Yu et al. (2008) is used. This method comprises two stages of estimation. In the first stage, maximum likelihood estimates are constructed. Second, bias corrections are computed for the coefficients of the dependent variables.

4.2 Data

The data set contains data for 14 NUTS3 regions of the Czech Republic. The data sample covers the period 2004-2015 on a yearly basis. Since we work with lagged variables, we lose one year of observations, and therefore, the data sample creates a balanced panel with 154 observations in total. The primary data sources are the monitoring systems MSSF, MSC2007 and MSC2014+ of the Ministry of Regional

[4] Moran's I (0.412), LMERR (39.479), LMLAG (58.612).

[5] The spatial models are estimated using the STATA command -xsmle which utilises the quasi-maximum likelihood estimator.

Development of the Czech Republic, an open source database of the Czech Statistical Office and the ARAD database of the Czech National Bank.

The financial sources from ESIF comprise the financial sources implemented under the National strategic reference framework for the first two programming periods (2004-2013) and the Partnership agreement for the last programming period (2014-2015). Additionally, the data from Rural Development Program were employed. The data set contains only the payments that can be addressed to individual regions, i.e., multi-regional programmes are not included. The database of the Czech Statistical Office is used to retrieve the data on regional GDP per capita, private expenditures on R&D activities, tertiary education and infrastructure. The GDP deflator is obtained from the ARAD database. An open source website tool (www.vzdalenostmest.cz) is used to compute distances between the capitals of regions. Real GDP, private expenditures and ESIF payments are expressed in thousands CZK. Descriptive statistics of data and correlations are summarised in Table 1 and Table 2 respectively.

Table 1 Descriptive Statistics (overall)

Variable	*Mean*	*SD*	*Min*	*Max*	*Obs.*
Real GDP p.c. growth	0.0194	0.0369	-0.0887	0.1042	154
Real GDP p.c.	326.3631	120.2245	239.1307	798.5595	154
Private expenditures on R&D p.c.	2.3085	1.6654	0.1464	8.3890	154
ESIF payments p.c.	7.5168	5.2689	0.0895	26.1402	154
Index of infrastructure	-1.1338	0.7393	-2.5554	0.2105	154
Number of people with tertiary education, a share of population	0.0948	0.0395	0.0405	0.2423	154

Table 2 Correlations

Variable	*(a)*	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*
Real GDP p.c. growth (a)	1.000					
Real GDP p.c. (b)	0.034	1.000				
Private expenditures on R&D p.c. (c)	0.059	0.791	1.000			
ESIF payments p.c. (d)	-0.261	-0.024	0.138	1.000		
Index of infrastructure (e)	-0.103	-0.524	-0.533	0.194	1.000	
Number of people with tertiary education, a share of population (f)	-0.039	0.864	0.859	0.268	-0.504	1.000

5. Results

5.1 "Standard" and Spatial Panel Regressions

The estimation procedure follows Mohl and Hagen (2010). First, the baseline model is estimated using pooled OLS estimator. Then, the fixed effects model is chosen as superior to pooled OLS and random effects model based on the F-test (5.37, p-value: 0.000), and the Hausman test (74.17, p-value: 0.000). Since the Wooldridge test of first-order autocorrelation (Wooldridge 2002) suggests its presence, clustered standard errors are employed to control for serial correlation. Lastly, the method proposed by Driscoll and Kraay (1998) is applied to adjust standard errors for heteroskedasticity, serial correlation and spatial correlation. The results of individual stages of the fixed effects model estimations are summarised in Table 3 (I-II).

Independently of the estimation procedure, the initial level of GDP per capita is negative and highly statistically significant. This result suggests the presence of the conditional convergence among regions of the Czech Republic. In other words, less developed regions catch up with more developed ones. Despite the shorter length of the time series (12 years), the model suggests clear evidence of this process. Nevertheless, the strong conclusion about the long-term convergence process cannot be made. The innovation variable is estimated with a positive impact; however, only in the estimation (I) is significant. The only variable that is insignificant in both regressions is the variable characterising the level of infrastructure in regions. This particular result might be caused by low time variance of the variable $infr$. The variable capturing the level of human capital is positively related to the regional growth of GDP and is significant in both estimations. The prominent variable of interest (the financial sources from ESIF) is positive and highly significant in the estimations (I) and (II). The estimated coefficient takes value 0.0028 and suggests that the financial sources from ESIF contributed on average by 1.96 p.p. annually to the growth rate of GDP in the Czech Republic during the period 2005-2015.

Table 3 The Estimations of the Fixed Effects and Spatial Fixed Effects[6] Models

	(I)	*(II)*	*(III)*	*(IV)*
Variables	*Fixed effects (clustered SE)*	*Fixed effects (Driscoll-Kraay SE)*	*SAR fixed effects (robust SE)*	*SAR fixed effects (Driscoll-Kraay SE)*
$y_{i,t-1}$	-0.0012***	-0.0012***	-0.0009***	-0.0009***
	(0.0002)	(0.0002)	(0.0002)	(0.0001)
$innov_{i,t-1}$	0.0068**	0.0068	0.0062**	0.0062
	(0.0029)	(0.0058)	(0.0032)	(0.0046)
$ESIF_{i,t-1}$	0.0028**	0.0028***	0.0016*	0.0016***
	(0.0012)	(0.0007)	(0.0008)	(0.0004)
$infr_{i,t-1}$	0.0203	0.0203	0.0143	0.0143
	(0.0161)	(0.0157)	(0.0104)	(0.0132)
$educ_{i,t-1}$	0.6514**	0.6514*	0.2920	0.2920
	(0.2219)	(0.3379)	(0.2019)	(0.2381)
sb_t	-0.0558***	-0.0558***	-0.0271***	-0.0271***
	(0.0082)	(0.0109)	(0.0082)	(0.0086)
constant	0.3783***	0.3783***		
	(0.0655)	(0.0966)		
ρ			0.4191***	0.4191***
			(0.0367)	(0.0475)
Observations	154	154	154	154
R-squared	0.5730	0.5730	0.5913	0.5913

Notes: *** p<0.01, ** p<0.05, * p<0.1.

The results stemming from the fixed effects model might be biased due to the spatial effects that are expected to be present among regions. To put it simply, a portion

[6] We use the STATA command -xsmle to estimate the model. When estimating the model, the command automatically supresses the constant and the opposite setting is not allowed.

of the achieved results might be explained by spillover effects among regions. So far, we accounted for the spatial correlation by correcting the standard errors according the Driscoll-Kraay method. Here we apply the spatial panel data regression method described by equation (5) to account for the spatial effects among regions. Based on the specification of the weight matrix we expect spatial dependence to be present for close neighbours rather than remote regions.

The estimation of equation (5) begins again with fixed effects model estimation. We correct the standard errors for heteroskedasticity, serial and spatial correlation. The results of the spatial panel fixed effects regressions are summarised in Table 3 (III-IV). The indicator testing the presence of the spatial spillover effects is given by the significance of the coefficient ρ. The coefficient ρ is positive and highly significant in both cases. Moreover, compared to the results of the previous regressions, the values of the coefficients of the explanatory variables are reduced. This suggests that a certain portion of the explanatory power of the variables was caused by the spillover effects. Such result is in line with other studies such as Ramajo et al. (2008), Moll and Hagen (2010), Lesage and Fischer (2008), De Dominicis (2014), or Fratesi and Perucca (2014).

The signs of all the coefficients are the same as in the “standard” regression. There is a negative highly significant impact of the initial real GDP per capita. Investment in R&D activities brings a positive effect (in estimation (III) insignificant while in estimation (IV) significant). The level of infrastructure brings an insignificant positive impact on the GDP growth rate. A positive insignificant effect is attributed to the level of education. Based on the spatial fixed effects model estimation, the coefficient on ESIF achieves the value 0.0016 which translates into an annual average effect of 1.12 p.p. of the GDP growth rate during the period 2005-2015. The estimated effect is lower by 0.84 p.p. of the GDP growth rate compared to the standard panel regression results.

5.2 Time Trend Included

Since drawing from ESIF is uneven with an increasing intensity at the end of the inspected time period, we control for the long-run impacts by including a quadratic time trend into the model. We re-run the regressions using the same procedures mentioned in the previous subsections and present the results in Table 4.

The time trend appears to be highly significant in all estimations. Inclusion of the time trend into the model affects considerably the magnitude of the estimated coefficients and standard errors almost in all cases. Moreover, standard error of the spatial coefficient increases. The variables describing R&D investment and infrastructure remain with the same signs as in the previous regressions, however, become even more insignificant. The variable characterising the quality of human capital turns out to be negative and insignificant which is not in line with common intuition. The main variable of interest (ESIF) is still highly significant in all four presented estimations. The fixed effects estimation delivers the value of the coefficient 0.0023 which is lower by 0.0005 compared to the baseline regression presented in Table 3. The spatial fixed effects with the time trend return the value of the ESIF coefficient 0.0013 which is lower by 0.0003 compared to the model without the time trend estimated by the same regression technique.

Table 4 The Estimations with the Time Trend

	(I)	*(II)*	*(III)*	*(IV)*
Variables	*Fixed effects (clustered SE)*	*Fixed effects (Driscoll-Kraay SE)*	*SAR fixed effects (robust SE)*	*SAR fixed effects (Driscoll-Kraay SE)*
	-0.0012***	-0.0012***	-0.0009***	-0.0009***
	(0.0003)	(0.0003)	(0.0002)	(0.0002)
$innov_{i,t-1}$	0.0041	0.0041	0.0046	0.0046
	(0.0032)	(0.0048)	(0.0034)	(0.0042)
$ESIF_{i,t-1}$	0.0023**	0.0023***	0.0013**	0.0013***
	(0.0009)	(0.0005)	(0.0006)	(0.0003)
$infr_{i,t-1}$	0.0171	0.0171	0.0127	0.0127
	(0.0143)	(0.0153)	(0.0099)	(0.0129)
$educ_{i,t-1}$	0.1261	0.1261	-0.0069	-0.0069
	(0.2096)	(0.3454)	(0.1912)	(0.2548)
sb_t	-0.0594***	-0.0594**	-0.0309***	-0.0309***
	(0.0068)	(0.0116)	(0.0077)	(0.0095)
$trend_t^2$	0.0004***	0.0004**	0.0002***	0.0002***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
constant	0.4040***	0.4040***		
	(0.0839)	(0.1074)		
ρ			0.3943***	0.3943***
			(0.0404)	(0.0479)
Observations	154	154	154	154
R-squared	0.5949	0.5949	0.6094	0.6094

Notes: *** p<0.01, ** p<0.05, * p<0.1.

5.3 Region Prague Excluded from the Data Sample

Figure 5 suggests that the region Prague appears to be an outlier in the data sample. It is the only region which does not fulfill the Objective 1 eligibility and its role in ESIF investment is different from the other Czech regions. Therefore, the results of the regressions might be biased. We exclude the region from the data set and re-run the regressions once again. The results of the estimations are summarised in Table 5. We present the results for the models without the time trend (I) and (III), and with the time trend (II) and (IV).

Compared to the regressions on the full data sample, all estimates are qualitatively the same, however, quantitatively different in some cases. The estimates of the impacts of R&D activities are lower while the estimates of infrastructure are higher. Both variables appear to be insignificant through the regressions (I) to (IV). Regarding the estimated coefficient on education, its value is higher and significant in case of the model without the time trend and the opposite holds for the model with the time trend. The estimates related to ESIF are almost unchanged compared to the estimations on the full data set. When we do not and do account for the time trend in the spatial fixed effect model, the estimated coefficients attain the value 0.0014 and 0.0013 respectively meaning the average annual contribution of ESIF to the GDP growth rate of 0.98 p.p. and 0.91 p.p. respectively.

Table 5 The Estimations on the Smaller Data Sample

	(I)	*(II)*	*(III)*	*(IV)*
Variables	*Fixed effects (Driscoll-Kraay SE)*	*Fixed effects (Driscoll-Kraay SE)*	*SAR fixed effects (Driscoll-Kraay SE)*	*SAR fixed effects (Driscoll-Kraay SE)*
$y_{i,t-1}$	-0.0016***	-0.0016***	-0.0012***	-0.0012***
	(0.0003)	(0.0003)	(0.0002)	(0.0002)
$innov_{i,t-1}$	0.0051	0.0035	0.0036	0.0027
	(0.0054)	(0.0048)	(0.0049)	(0.0047)
$ESIF_{i,t-1}$	0.0025***	0.0021***	0.0014***	0.0013***
	(0.0005)	(0.0002)	(0.0004)	(0.0003)
$infr_{i,t-1}$	0.0239	0.0239	0.0195	0.0199
	(0.0146)	(0.0140)	(0.0129)	(0.0125)
$educ_{i,t-1}$	0.8908**	0.1598	0.5702**	0.1235
	(0.2938)	(0.3133)	(0.2229)	(0.2715)
sb_t	-0.0525***	-0.0562***	-0.0293***	-0.0338***
	(0.0099)	(0.0111)	(0.0083)	(0.0102)
$trend_t^2$		0.0004**		0.0003***
		(0.0001)		(0.0001)
constant	0.4306***	0.5016***		
	(0.0985)	(0.1062)		
ρ			0.3694***	0.3355***
			(0.0538)	(0.0571)
Observations	143	143	143	143
R-squared	0.6014	0.6260	0.5970	0.6138

Notes: *** p<0.01, ** p<0.05, * p<0.1,

5.4 Summary of the Results

Table 6 summarises the results of the estimations concerning the ESIF variable in a compact form. As Table 6 shows, the estimated coefficients of the model with the time trend are lower to their no-time-trend counterparts by 0.0001 to 0.0005 yielding the difference in the estimated average annual growth rate contribution of 0.07 p.p. to 0.35 p.p. The estimated coefficients on the smaller data sample (excluding the region Prague) take slightly smaller values compared to the estimates on the full data sample. This result is not surprising since we exclude from the estimation the most developed region, Prague, that considerably exceeds the economic performance of the other regions measured by annual GDP per capita and receives the second lowest financial support from ESIF at the same time. The time trend seems to affect the results in the fixed effects estimations rather than in the spatial panel fixed effects estimations. Our regression results show that when accounting for spillover effects, performing the analysis on the full or smaller data set, and including or not including the time trend, the estimated average annual growth rate contribution of ESIF within the inspected time period amounts to 0.91-1.12 p.p.

Table 6 The Summary of the Estimation Results on the ESIF Variable

		Estimated coefficient on $ESIF_{i,t-1}$ ***(Driscoll-Kraay SE)***		***Estimated average annual growth rate contribution***	
Full data sample	*Time trend*	*Fixed effects*	*SAR fixed effects*	*Fixed effects*	*SAR fixed effects*
yes	no	0.0028*** (0.0007)	0.0016*** (0.0004)	1.96 p.p.	1.12 p.p.
yes	yes	0.0023*** (0.0005)	0.0013*** (0.0003)	1.61 p.p.	0.91 p.p.
no	no	0.0025*** (0.0005)	0.0014*** (0.0004)	1.75 p.p.	0.98 p.p.
no	yes	0.0021*** (0.0002)	0.0013*** (0.0003)	1.47 p.p.	0.91 p.p.

Notes: *** p<0.01, ** p<0.05, * p<0.1.

6. Conclusions

Although the use of quantitative methods aimed at the assessment of the impacts of EU funds is a common approach, there are few such studies in the Czech Republic. Therefore, the paper contributes to the Czech current literature by (i) investigating the impact of ESIF on economic growth of regions of the Czech Republic using the quantitative modelling approaches and (ii) applying dynamic panel data regression techniques controlling for spatial effects. In particular, this paper reveals that the projects co-financed from ESIF for approximately 939 billion CZK in period 2004-2015 do have a positive significant effect on economic growth of regions of the Czech Republic. Based on the selected data sample, the estimated average annual impacts on the GDP growth rate vary between 0.91-1.12 p.p.. The results also indicate strong regional spillover effects.

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