Investment into Low-Carbon Economy in the CEE NUTS-2 Regions: Are EU Funds Used where Needed?

Ľubica Štiblárová[1] | *Technical University of Košice, Košice, Slovakia*

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Abstract

This paper explores the spending decisions about the EU Cohesion Policy 2014–20 investment in the low-carbon economy in the NUTS 2 regions of Central and Eastern European countries with regard to their climate need, proxied by the carbon emissions. By estimating non-spatial and spatial econometric models, which take into account the spatial scope of the Cohesion Policy, we do not confirm a statistically significant positive relationship between climate need proxied by carbon emissions in 2013 and the EU funds to a low-carbon economy in the programming period 2014–20. Our results, therefore, suggest that the EU funds with the low-carbon thematic objective have not been primarily spent in the regions with the highest carbon emissions prior to the examined programming period, calling for increasing awareness and necessary technical assistance for the beneficiaries, along the place-based strategies in the implementation of the Cohesion Policy in the next programming periods.

Keywords	DOI	JEL code
European structural and investment funds, allocation, low-carbon economy, spatial dependence, carbon emissions	*https://doi.org/10.54694/stat.2023.13*	*C21, E22, F36*

INTRODUCTION

The European Union (EU) is considered as a leader in focusing on the topic of climate change and mitigating its effects (Schreurs and Tiberghien, 2010; Siddi, 2020; Antimiani, Costantini and Paglialunga, 2023). Not only the recent Fit for 55 package proposed by the European Commission in 2021 aims to decrease net greenhouse emissions by at least 55% by 2030 (compared to the levels in 1990), but the EU considers carbon neutrality as its long-term goal in climate and energy policy (Schreurs and Tiberghien, 2010; Panarello and Gatto, 2023). The European Green Deal (EGD) should serve that purpose; the EGD has the ambition of zero net greenhouse emissions by 2050, which would ensure the status of the EU

[1] Faculty of Economics, Technical University of Košice, Němcovej 32, 040 01 Košice, Slovakia. E-mail: lubica.stiblarova@tuke.sk, phone: (+421)556022665.

as the first carbon-neutral continent (Cassetti et al., 2023; European Commission, 2023a). Some authors consider it as a *"roadmap of key policies for the EU's climate agenda"* (Siddi, 2020: 4).

This climate action, later translated into sustainable economic growth and decarbonization (Kedward and Ryan-Collins, 2022; Panarello and Gatto, 2023), should be financed by the NextGenerationEU Recovery Plan and the recent EU's common budget 2021–27 through the European Investment and Structural funds. For objective Greener Europe, more than 127 billion EUR is planned to be invested in lowering carbon emissions, circular economy, and mitigation of climate change within the period 2021–27 (European Commission, 2023b).

The EU Cohesion policy has already been supportive in promoting the EU's transition to a low-carbon economy in previous programming periods via European Regional Development Fund (ERDF). In the programming period 2014–20, more than 60 billion EUR have been planned to be invested in the low-carbon economy, while there has also been an obligatory condition to allocate a particular minimum share of the ERDF payments to the low-carbon economy thematic objective (European Commission, 2023c).[2] The member states exceeded these requirements and scheduled double the amount spent in the previous programming period 2007–13.

To provide desired effects, i.e., a reduction of carbon dioxide emissions, there should also be effective allocation mechanisms serving that purpose. Were investments into a low-carbon economy spent in the climatically disadvantaged regions? While there has been provided an excessive empirical evidence on the effects of EU funds in terms of reducing regional disparities and promoting economic growth (see, e.g., Ederveen, De Groot and Nahuis, 2006; Eggert et al., 2007; Becker, Egger and Von Ehrlich, 2010; Mohl and Hagen, 2010), the spending strategies of the member states' authorities themselves, i.e., whether financial resources are primarily implemented in the locations where needed, are not in the main area of interest, although, should be considered as crucial driving forces of the EU economic effects as well (Medve-Balint, 2018).

The aim of this paper is to answer this research question on the sample of Central and Eastern European (CEE) NUTS2 regions during the programming period 2014–20. We choose the CEE countries as the EU recipients who richly draw on the Cohesion Policy, but also due to the fact that compared to the Western European member states, these countries lag behind in the fulfillment of the EU's climate and energy goals (see, e.g., CORDIS, 2022). It is therefore more than appropriate to invest in the regions where most needed.

The rest of this paper is organized as follows. The first section provides a literature review on the effects of the Cohesion Policy in the EU. The second section describes a methodology and used data on examining the relationship between the low-carbon investment on the NUTS2 level and *"climate need"* measured as CO_2 emissions in the CEE countries. We provide results and discussion in the next section, while the last section concludes our comments, with policy recommendations on this matter.

1 LITERATURE REVIEW

The Cohesion Policy plays an important role in the sustainable transition of the EU member states; this task does not only consist of financing low-carbon investment but also in supporting the transformation of socio-economic and technical conditions. This includes, for instance, the development of infrastructure, technologies, or building capacities, which should be later translated into a systematic change in unsustainable production and consumption systems (European Commission, 2020b).

In this regard, the main branch of the empirical research is, therefore, devoted to the effects of the Cohesion Policy on convergence, economic growth, and/or employment. Here, the authors

[2] At least 20% of the payments from ERDF had to be allocated to low-carbon economy objective in more developed regions, 15% in transition regions, and 12% in less developed regions.

mostly rely on the β-convergence models from neoclassical growth theory (Baumol, 1986; Barro and Sala-i-Martin, 1992).

A majority of studies confirm a positive contribution of the Cohesion Policy to the recipient member states (see, e.g., Cappelen et al., 2003; Ederveen, De Groot and Nahuis, 2006; Ramajo et al., 2008; Mohl and Hagen, 2010). For instance, Cappelen et al. (2003) find a positive effect of the EU funds payment on regional economic growth performance, stating that historical changes in funds functioning helped to build an even more effective Cohesion Policy. Counter-factual evaluation of the Cohesion policy is provided by Becker, Egger, and Von Ehrlich (2013), or Pellegrini et al. (2013), who with the use of regression discontinuity design find a positive impact of the Cohesion Policy in the EU regions during 1994–2006. In a similar way, the positive causal effects of the EU funds on employment are observed in the Italian Objective 1 regions by Giua (2017).

Analogously, Mohl and Hagen (2010) show that Objective 1 payments do have a positive, statistically significant effect on regional GDP in EU countries during the programming period 2000–06.[3] However, Mohl and Hagen (2010) also state that the total amount of EU funds for Objectives 1, 2, and 3 do not seem to have a statistically significant positive effect on regional economic growth. Becker, Egger and Von Ehrlich (2010) confirm a positive effect of the EU funds for Objective 1 on EU regional GDP per capita growth, but they do not find employment growth effects at all. Similar evidence is brought by other studies which do not find significant effects of the Cohesion Policy (see, e.g., Boldrin and Canova, 2001).

Compared to the aggregate view on the EU funds, a lower granularity can take into account unobserved heterogeneity regarding sectors in the economy, objectives of the Cohesion Policy, and regions (see, e.g., Mohl and Hagen, 2010; Scotti, Flori and Pammolli, 2022). In this vein, Scotti, Flori and Pammolli (2022) provide detailed evidence of the effects of the EU funds across different sectors in the programming period 2007–14.[4] The authors find that the investment promising instantaneous and long-term growth has been confirmed for the energy, R&D, and transport sectors. On the contrary, environmental investment does not seem to provide an immediate stimulus to regional development.

In particular, the issue of environmental investments within the Cohesion Policy and their impact has been addressed, for example, by Ptak (2016), Streimikiene (2016), Kozera et al. (2022), or Gouveia, Henriques and Amaro (2023). Streimikiene (2016) investigates the role of EU funds in supporting sustainable energy development, with the main objective of energy efficiency allowing, among other things, a reduction of carbon emissions. The author focuses on the Baltic states in the programming periods 2007–13 and 2014–20 and states that the EU payments helped the Baltic countries to increase their energy productivity, especially Lithuania. The share of renewables has increased as well, where Estonia dominated in this area.

Kozera et al. (2022) examine low-carbon investment within the Cohesion Policy 2014–20 implemented in Polish municipalities. The authors focus on regional EU payments and find differences across regions, but also supported areas. For instance, the greatest portion of the EU funds has been used to promote infrastructure for clean transport and its improvement regarding energy efficiency.

Ptak (2016) discusses the expected effects of EU funds in the programming period 2014–20 with regard to the EU climate and energy targets in 9 EU member countries.[5] While the highest effect of the EU funds in the area of a low-carbon economy is expected in Poland, Ptak (2016), with a few exceptions, considers the achievement of set goals as a challenge. At the same time, the author states that selected countries differ widely in terms of meeting environmental targets.

[3] Mohl and Hagen (2010) consider the following EU countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

[4] The authors focus on particular sectors: energy, environment, human resources, IT infrastructure, research and development, rural development, social infrastructure, tourism, and transportation.

[5] Austria, Czech Republic, Estonia, Germany, Latvia, Lithuania, Poland, Slovakia, and the United Kingdom.

Gouveia, Henriques and Amaro (2023) examine the efficiency of ERDF expenditure intended to support a low-carbon economy in 23 EU member states.[6] Using a Value-Based Data Envelopment Analysis (VBDEA), the authors only find less than half of examined countries as efficient recipients; while Spain seems to be the leading country in robust efficiency, the Czech Republic is the worst in the list of inefficient member states. Due to the discovered inefficiency, Gouveia, Henriques and Amaro (2023) suggest providing enhanced EU financing mechanisms and technical expertise regarding low-carbon economy for the recipient countries.

Dilba et al. (2016) present even more unfavorable evidence in their report. The authors focus on the spending plans of the EU funds and projects regarding climate in nine CEE countries.[7] In spite of the large available financial resources, Dilba et al. (2016) state that the full potential for the clean energy transition of the CEE countries has been unexploited and the climate requirements under the EU law have been implemented superficially. For instance, the EU funds in Poland have been rather spent on sustaining than transforming the recent coal-based economy.

Liobikiene and Mandravickaite (2016) investigate the link between the Cohesion Policy and greenhouse gas emissions in the programming period 2007–13 from the production-based perspective. The authors state that despite technological progress with regard to emissions, it is not possible to compensate for the effect of production scale in the Baltic countries, Bulgaria, or Poland. Also, Liobikiene and Mandravickaite (2016) declare that economic growth generated by the Cohesion Policy did not significantly contribute to structural changes to decrease greenhouse gas emissions.

Ionescu, Zlati and Antohi (2021) focus on Cohesion Policy from the point of view of the sustainability goals of the 2030 Agenda. Based on a cluster analysis in the monitored period 2006–20, the authors emphasize the need to reduce disparities between EU regions from the point of view of sustainable development. Ionescu, Zlati and Antohi (2021) also call for the improvement of sustainable development through the promotion of regional financial autonomy and administrative capacity.

For the emissions, Naqvi (2021) finds similar heterogeneous evidence, both spatial and temporal in EU NUTS 2 regions. Why are the effects of the Cohesion Policy noticeable in some countries/regions and negligible in others? There might be various reasons behind this matter – both on the aggregate and regional/sectoral levels. In this regard, the previous studies aim attention to the recipients' absorption capacity, institutional quality, or mismatch between the development needs and spending strategies of EU funds.

The first mentioned, the recipients' absorption capacity, has been proven to be one of the factors determining the effects of the EU funds. The European Commission (2020a) claims that it is vital to promote absorption capacity through country-specific suggestions, such as effective institutions and tax systems, anti-corruption frameworks, etc., which can be later translated into ease of investment. A similar scenario in terms of speeding up processes is recommended at the EU level in order to protect the EU's financial interests. In accordance with this, Arbolino and Di Caro (2021) find that an increased absorption rate and allocation of EU funds are associated with a reduction of regional employment losses during recessions, calling for a prompt and accurately managed Cohesion Policy. However, the recessionary periods tend to be associated with the decreased member state's ability to spend EU funds, i.e., the absorption paradox (Tatulescu and Patruti, 2014).

For institutional quality, it is expected that high-quality institutions are allied with higher GDP per capita, and employment, for which they present one of the prerequisites of long-term economic and social convergence (see, e.g., Mascherini and Mizsei, 2022). Montresor, Pecci and Pontarollo (2020)

[6] The sample consists of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Romania, Slovakia, Spain, Sweden, the United Kingdom.

[7] Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Slovakia.

examine this topic in 180 European NUTS-2 regions during the time period 1989–2006 using a spatial econometric approach. The authors find the conditional effect of regional institutional quality. Based on the results, Montresor, Pecci and Pontarollo (2020) confirm that an increase in regional institutional quality is associated with higher effectiveness of Objective 1 within the Cohesion Policy, because of which they recommend supporting regions' institutional capacity in order to improve the efficiency of the EU funds on productivity growths.

Similar suggestions are provided by Mendez and Bachtler (2022) who investigate the relationship between the quality of government and administrative performance for ERDF of 173 European regions in the time period 2007–13. The authors state that the quality of government seems to be a crucial driver of administrative performance and a high government quality may boost the Cohesion Policy implementation.

Jager (2022) confirms the importance of the institutions for the EU innovation projects in the Italian regions during 2007–20 only in the short-term; as the author claims, a high institutional quality allows for strengthening the effectiveness of the EU funds on patents.

While the empirical literature offers extensive results about the shortcomings of the Cohesion Policy with respect to the absorption capacity and institutional quality, there is a lack of systematic evidence on the possible mismatch between the development needs of the member states and their spending strategies of EU funds. A rare exception presents a study by Medve-Balint (2018) which examines Southern and Eastern EU member states' national spending strategies in two programming periods of the Cohesion Policy (2007–13 and 2014–20) with respect to the recipients' domestic development needs. The author examines five spending strategies – physical infrastructure, R&D and info-communication technology, business support, human capital, and institution building. With the use of Kendall's tau-b correlation, Medve-Balint (2018) reports that the spending strategies do not correspond to the domestic development needs of the recipient countries, indicating a possible misallocation problem.[8] In particular, recipients tend to prioritize physical infrastructure projects over R&D or human capital investment, which could bring long-term benefits.

This paper investigates a similar issue, with emphasis placed on the low-carbon theme in the Cohesion Policy, such as Kozera et al. (2022). However, our approach differs from the seminal work of Medve-Balint (2018) in several ways, by which we contribute to the recent empirical knowledge on this matter. Firstly, we focus on the regional level of the EU funds and the related climate needs of the regions. The regional examination can not only complement country-level analysis but may reveal detailed evidence, i.e., capture the within-country heterogeneity (Rodriguez-Pose and Ganau, 2022) on the actual EU spending in the CEE regions with respect to their climate needs.

The rationale for looking at the regional level is quite straightforward; EU funds are not distributed to specific regions, but at the national level. It must be said, however, that data on the socio-economic development of NUTS-2 regions are used to calculate the amount of national EU funding, after which each member state submits the proposal on how the total allocation will be handled through national and/or regional programmes (for more, see, European Commission, 2021).[9] In other words, the European Commission does not allocate the EU funds directly to the regions, but to programmes and categories of regions due to the fact that the EU Cohesion Policy is coordinated, not a common policy. This gives the opportunity for discrepancies between the actual expenditure and the needs of given regions.

Secondly, we do not rely on correlation coefficients, but estimated econometric model where we also allow for spatial dependence. The previous literature on the effects of the EU funds has highlighted the spatial scope of the Cohesion Policy since the spillover effects from the EU funds may arise

[8] In Medve-Balint's (2018) paper, misallocation can be understood as a situation when development needs in selected spending categories do not correspond to the share of funds allocated to them.

[9] In the programming period 2014–20, data on the socio-economic development of NUTS-2 regions have been used to divide regions into three categories: "less developed", "transitional", and "more developed".

in the spirit of the new economic geography (see, e.g., Krugman and Venables, 1995; Mohl and Hagen, 2010; Smit et al., 2015; Antunes et al., 2020; Scotti, Flori and Pammolli, 2022). Moreover, Scotti, Flori and Pammolli (2022) highlight the role of spatial spillovers in the EU funds allocation with regard to the granularity of data; the authors observe spillover effects that differ across sectors and geographical levels. For instance, the highest indirect spillovers are detected in the transport sector. Omitting the spatial aspect of the EU funds could thus lead to biased estimates.

2 METHODOLOGY AND DATA

To examine the relationship between the regional expenditure on EU funds to a low-carbon economy and the carbon dioxide emissions in the CEE regions, we estimate the baseline model in the following form:

$$EU\,funds\_carbon_i = \beta_0 + \beta_1 \log CO_{2i} + \textstyle\sum_{c=1}^{C} \delta_c \log CV_{ci} + \mu_j + \varepsilon_i \,, \tag{1}$$

where $EUfunds\_carbon_i$ presents the total eligible expenditure spent on the EU projects with the thematic objective low-carbon economy, CO_{2i} stands for carbon dioxide emissions which presents our proxy for *"climate need"*, and *CVci* stands for control variables (human capital in R&D, population, area, unemployment, and GDP per capita, namely) for the regions *i* within the programming period 2014–20. We also add a dummy variable (μ_j) denoting recipient country *j* to control for country-specific effects, and ε_i stands for the error term.

The model is estimated for cross-sectional data on the NUTS 2 level in the CEE countries.[10] Since the goal is to examine whether the EU funds' expenditure of the programming period 2014–20 has been spent in regions with high *climate need* (i.e., with a high level of carbon dioxide emissions), our main variable of interest, CO_{2i}, measures emissions prior to the start of the programming period, i.e., in the year 2013.[11] The rationale behind the decision of a lagged CO_2 variable in our model specification lies behind the fact that the European Parliament and the European Council decide on the total budget for the recipient countries based on national governments' proposals before the start of the programming period. Since the EC does not allocate expenditure directly to the regions which need it, national governments, in accordance with the EU allocation rules, have freedom in selecting their spending priorities (see, e.g., Medve-Balint, 2018). This can possibly lead to the situation when final expenditures are spent in regions which do not have such an urgent climate need from the point of view of carbon emissions). The sign of the estimated coefficient can, therefore, reveal whether EU funds have corresponded to the actual climate need (positive estimate) or on the contrary, have mismatched the climate need measured as regional carbon emissions (negative estimate), which may signal the possible misallocation of the EU funds on the low-carbon economy.[12]

Unlike evidence on the misallocation brought by Medve-Balint (2018), we extend the model by considering spatial dependence in the EU funds implementation in the spirit of new economic geography (Krugman and Venables, 1995). The previous empirical literature suggests that not only the spatial patterns but also spillover effects may appear in the context of the Cohesion Policy (see, e.g., Mohl and Hagen, 2010; Scotti, Flori and Pammolli, 2022). For this reason, we test spatial dependence in EU funds expenditure using Moran's I test, and then, to account for these possible effects, we estimate spatial econometric models. Here, we follow Elhorst (2014) and apply a specific-to-general approach (Elhorst,

[10] All NUTS 2 regions of the CEE countries are included in the analysis, regardless of their status (more developed/transition/less developed regions) since all regions have been supported by EU funds within the low-carbon economy thematic objective under "Greener, carbon-free Europe" objective (PO02).

[11] The remaining (control) variables in the model are measured as the average values for the programming period 2014–20 to take into account the socio-economic conditions of the given period.

[12] While referring to misallocation, we follow the terminology used in Medve-Balint (2018) – for more, see Footnote 8.

2014) by first estimating the non-spatial linear model and then assessing whether the baseline model should be extended by interaction spatial effects.

As a result, we choose a spatially lagged explanatory variables (SLX) model which includes exogenous interaction effects ($\boldsymbol{WX}$):

$$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{WX\theta} + \boldsymbol{\varepsilon}\,, \tag{2}$$

and spatial Durbin error (SDEM) model which extends SLX model (Formula 2) by considering the spatial dependence among the observation in the error term ($\boldsymbol{u} = \boldsymbol{\lambda Wu} + \boldsymbol{\varepsilon}$).[13] The estimation of the SLX and SDEM models allows us to examine direct effects of explanatory variables (through vector of estimated regression coefficients $\boldsymbol{\beta}$ related to the matrix of explanatory variables $\boldsymbol{X}$), but also indirect effects through the coefficients related to spatially lagged explanatory variables ($\boldsymbol{\theta}$).

The complete variables description with data sources is available in Table A1 in the Annex. The dependent variable, *EUfunds_carbon*, has been calculated based on individual location data published by the European Commission (DG REGIO) as a sum of total eligible expenditure for implemented projects with the thematic objective low-carbon economy, under *"Greener, carbon-free Europe"* objective (PO02), mapped to NUTS 2 regions (as % GDP). The proxy for climate need, the CO_{2i} variable, has been also individually calculated for the NUTS 2 regions from yearly emission gridmaps published in the EDGAR database (Emissions Database for Global Atmospheric Research). Here, we joined spatial point data of carbon dioxide emissions based on longitude and latitude coordinates to NUTS 2 polygons. The administrative NUTS 2 boundaries are retrieved from the GISCO statistical unit dataset provided by Eurostat.

The control variables have been selected in accordance with the previous empirical studies dealing with regional convergence and effects of EU funds (see, e.g., Cappelen et al., 2003; Kozera et al., 2022; Scotti, Flori and Pammolli, 2022). We control for human capital in R&D activities ($R\&D_i$), total regional area ($Area_i$), population (Pop_i) in examined NUTS 2 regions, unemployment ($Unemp_i$), and regional GDP per capita ($GDPpc_i$). The inclusion of these variables allows us to examine whether projects with low-carbon theme have been implemented in regions with higher or lower share of human capital in R&D ($R\&D_i$), in larger rural areas or rather smaller, but more dense cities ($Area_i$, Pop_i). For the remaining variables,

Table 1 Descriptive statistics

	N	Min	Mean	Median	S.D.	Max
EUfunds_carbon	61	0.165	2.656	2.627	1.638	8.324
CO_2	61	9 070.088	102 421.761	48 713.267	149 122.978	815 499.350
R&D	58	0.112	0.839	0.557	0.813	3.712
Pop	58	642 679.286	1 726 750.333	1 446 866.357	798 574.704	4 511 471.143
Area	61	496.000	18 595.276	16 263.000	12 478.170	64 586.000
Unemp	61	13.386	46.121	40.371	23.222	101.200
GDPpc	61	9 285.714	20 440.984	17 771.429	9 758.162	58 385.714

Source: Own elaboration based on data from EDGAR, the European Commission, and Eurostat

[13] The SLX and SDEM models have been selected based on information criteria (AIC, BIC), the log-likelihood value, and the likelihood ratio (LR) test. The SDEM model has been selected by AIC and the log-likelihood value, while the SLX model has been recommended by BIC and LR test, for which we report the results of both model estimations.

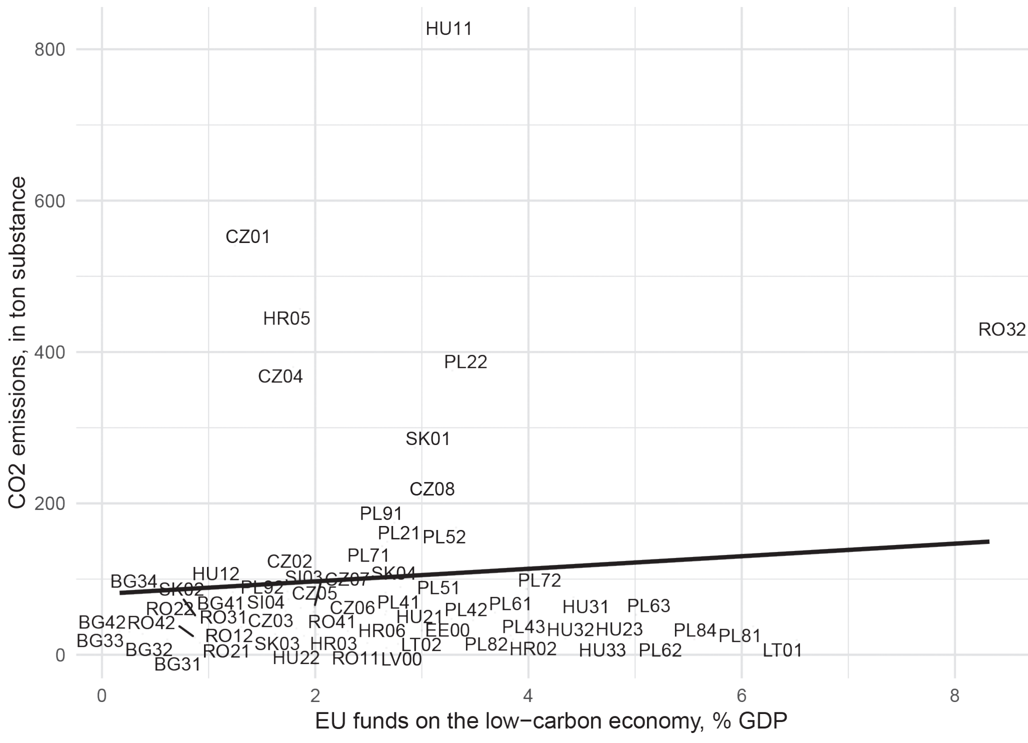
$Unemp_i$ and *$GDPpc_i$*, we expect that EU funds are primarily implemented in less developed regions in terms of lower GDP per capita and/or higher unemployment.

Our dataset consists of NUTS 2 regions in the Central and Eastern European countries. We provide a list of names of considered NUTS 2 regions in Table A2 in the Annex, while descriptive statistics is available in Table 1.

3 RESULTS AND DISCUSSION

In this section, we first depict the overall relationship between CO_2 emissions and EU expenditure on low-carbon within the NUTS 2 CEE regions (see Figure 1) and discuss the spatial distribution of considered variables, focusing on regional differences. Then, based on the examination of spatial dependence, we provide estimation results for non-spatial and spatial models and draw conclusions from the analysis.

Figure 1 Relationship between CO_2 emissions and EU low-carbon investment in NUTS 2 CEE regions

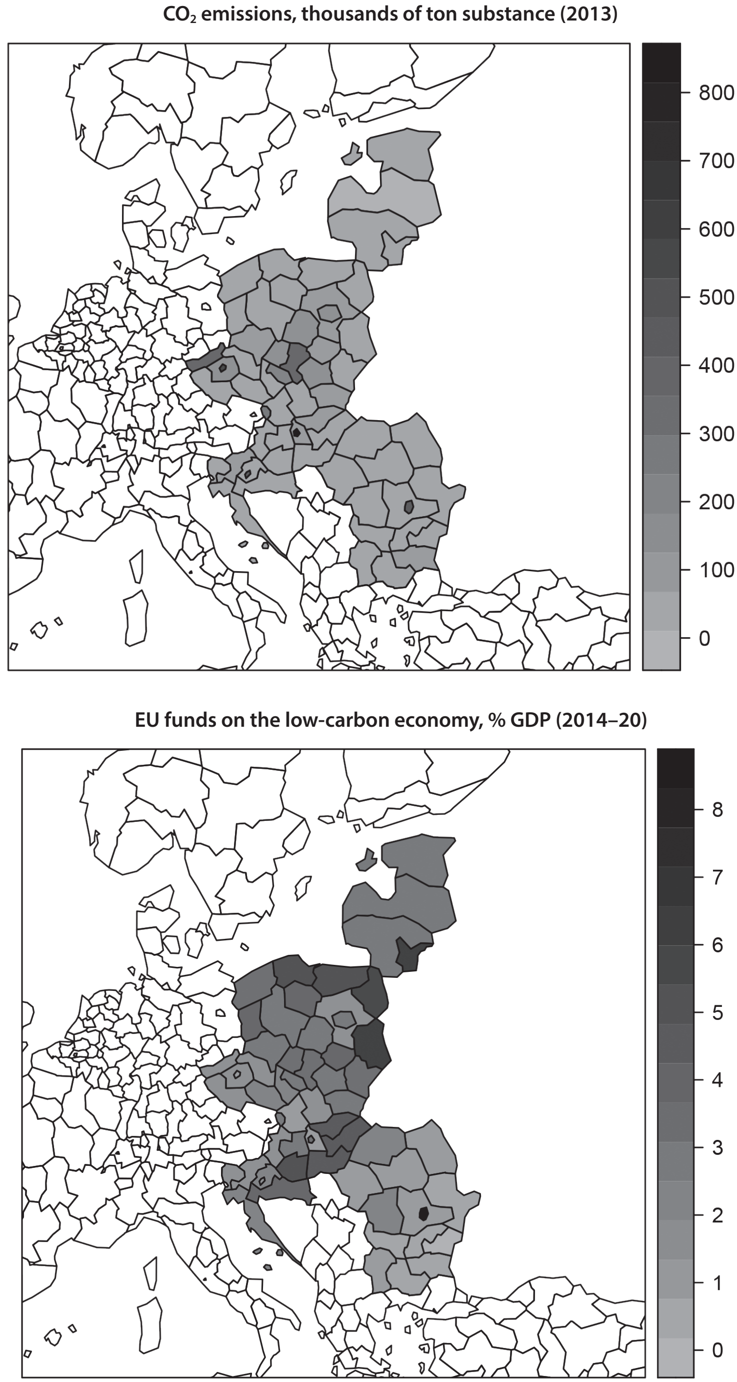


Source: Own elaboration based on data from EDGAR and the European Commission

From Figure 1, we cannot easily say that the EU funds for the low-carbon economy have been spent in the regions with higher carbon emissions. The trend line has a slight positive slope which is rather caused by unusual observations – by excluding them, the line is almost flat. The unusual observations mostly present capital cities, e.g., Budapest (HU11), Prague (CZ01), or Zagreb (HR05).

These metropolises show significantly higher emissions (see Figure 2, left) compared to spent EU funds in a low-carbon economy. We can assume that such results are related to the fact that regions in which the capital cities are located often show higher growth compared to the others. Hence, with gaining

Figure 2 Spatial distribution of CO_2 emissions and EU low-carbon investment in NUTS 2 CEE regions



Note: © EuroGeographics for the administrative boundaries.
Source: Own elaboration based on data from EDGAR and the European Commission

a status of transition or more developed regions, there is a general decrease in EU expenditure which is in line with e.g., Prota, Viesti and Bux, (2020).

On the other hand, such conclusions cannot be drawn for the Romanian capital, Bucharest, which receives a huge portion of EU funds for the low-carbon economy (% of GDP) and at the same time, peaks in pollution mainly because of traffic jams and motor vehicles in Romania (see also Figure 2, left).

Bucharest belongs to the most polluted cities in Europe and even the European Commission reproached the Romanian government for systematically exceeding the PM10 concentration limits in this region since 2007, failing to improve this situation (for more, see, European Commission, 2018). Overall, poor environmental conditions in Romania can be attributed to the transport and energy sectors, with the country's dominating long-standing orientation on the oil and gas industry (see, e.g., Fernandez et al., 2022).

Along the mentioned capital cities, the remaining regions of our sample do not show large discrepancies at the given scale, except for the Polish region Silesia (PL22) which experiences significantly more carbon emissions compared to other Polish areas. Silesia is one of the most urbanized and industry-oriented Polish regions where coal mining and related sectors played a crucial role in determining regional economic growth for a long time. Also for this reason, a smooth transition to a low-carbon economy in this region should be helped through EU funds.

While comparing the spatial distribution of carbon emissions and EU low-carbon investment (Figure 2), we can again state that there is no clear similar pattern, i.e., it does not seem that high shares of the EU funds are allocated to regions with high levels of carbon emissions, as in Figure 1 (except for Bucharest). This evidence might be related to the built-in internal mechanisms and criteria for the distribution of funds, i.e. the concentration principle, which concerns the territorial agenda. A high portion of the EU funds (% GDP) on the low-carbon economy is going to Vilnius County (LT01), Polish, and Hungarian regions where neighboring regions also experience similar levels of investment, which can suggest spatial autocorrelation in the EU funds expenditure.

Table 2 Spatial autocorrelation (Moran's I) – EU funds on low-carbon economy

	Spatial weights matrix W	
	Contiguity-based	**Distance-based (6-nearest neighbors)**
EU funds on the low-carbon economy	0.311*** (<0.001)	0.177** (0.002)

Note: We report Moran I statistic (p-values in parentheses). *p < 0.1, **p< 0.05, ***p< 0.01.
Source: Own elaboration based on data from the European Commission

To test this, we apply Moran's I test for which the results are provided in Table 2. The Moran's I test confirms that the spatial distribution of the EU funds is positively autocorrelated – this result is statistically significant and robust using either contiguity-based or distance-based spatial weights matrix W. Our evidence of spatial dependence is, therefore, in line with previous studies of e.g., Mohl and Hagen (2010), Scotti, Flori and Pammolli (2022) and omitting this could lead to biased estimates.

In order to avoid such a problem, the non-spatial model where we investigate the effect of carbon need on the EU funds expenditure on the low-carbon economy is followed by spatial model estimation. The results are provided in Table 3. In all model specifications (columns (I)–(VIII)), we do not confirm a statistically significant relationship between a climate need proxied by carbon emissions in 2013 and the EU funds to a low-carbon economy in the programming period 2014–20 for NUTS 2 CEE regions. Our evidence, therefore, validates the previous results of Medve-Balint (2018) about the possible mismatch between the domestic development needs and spending strategies of the EU funds. While Medve-Balint (2018) claims that EU funds spent on the R&D and human capital projects did not reflect the domestic development needs of recipient countries in 2007–20, our model estimations provide similar evidence,

Table 3 Estimation results

	Non-spatial models						Spatial models	
	OLS						SLX	SDEM
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
Constant	−1.166 (1.127)	−0.473 (1.034)	4.595* (2.333)	3.956 (2.537)	11.158** (4.362)	9.889* (5.134)	7.467 (10.970)	10.573 (7.509)
CO_2	0.029 (0.104)	−0.024 (0.094)	−0.010 (0.092)	0.098 (0.128)	0.062 (0.116)	0.049 (0.142)	0.211 (0.178)	0.177 (0.113)
R&D		0.216* (0.128)	0.249* (0.127)	0.351** (0.168)	0.459** (0.170)	0.415** (0.189)	0.534** (0.234)	0.468*** (0.151)
Pop			−0.374** (0.185)	−0.537** (0.249)	−1.160*** (0.383)	−1.227*** (0.395)	−1.316*** (0.462)	−1.506*** (0.297)
Area				0.189 (0.210)	0.150 (0.194)	0.173 (0.207)	0.352 (0.266)	0.357** (0.166)
Unemp					0.633** (0.247)	0.695** (0.297)	0.547 (0.357)	0.727*** (0.232)
GDPpc						0.197 (0.491)	0.158 (0.552)	0.376 (0.352)
Lag.CO_2							0.064 (0.312)	0.038 (0.217)
Lag.R&D							−0.144 (0.352)	−0.078 (0.216)
Lag.Pop							−1.151 (0.986)	−1.498** (0.668)
Lag.Area							0.504 (0.545)	0.493 (0.349)
Lag.Unemp							0.218 (0.678)	0.635 (0.478)
Lag.GDPpc							1.124 (1.011)	1.208* (0.621)
Country-specific effects	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.660	0.694	0.716	0.722	0.758	0.759	0.865	0.871
N	61	58	58	58	58	58	58	58
AIC	99.900	94.395	92.037	92.933	86.755	88.528	86.841	86.114
BIC	127.341	123.241	122.944	125.900	121.783	125.616	156.896	158.230
LogLik							−9.421	−8.057
LR test							−2.727 (0.099)	

Note: Robust standard errors are reported in parentheses; *p < 0.1, **p < 0.05, ***p < 0.01. For LR test, we report LR ratio (p-value in parentheses). The spatial models are estimated using a contiguity-based spatial weights matrix (the model estimations using a distance-based spatial weights matrix are qualitatively similar, and thus, not included for the sake of brevity).
Source: Own elaboration based on data from EDGAR, the European Commission, and Eurostat

but for the EU low-carbon investment and on a lower granularity of data, at the regional level for CEE countries. For the country-specific evidence, we can only refer to Kozera et al. (2022) who calculate the correlation between the Polish municipalities' EU investment in a low-carbon economy and air pollutant emissions. While the authors find a correlation of 0.64 between the value of projects per 100 km^2 and air pollutant emissions, there is almost zero correlation between the value of projects per 1 000 inhabitants and air pollutant emissions.

The reasons behind this situation may also lie in the readiness and abilities of the actors to prepare their projects at this level. As mentioned by Vironen, McMaster and den Hoed (2019) the recipients within this thematic objective may present small organizations with limited capacities and a lack of technical expertise, which can hinder the preparation of project proposals of sufficient quality. A similar problem could also arise on the side of the implementing authorities, where recipients could have problems obtaining the necessary information due to the newness of the theme. From the perspective of a low-carbon economy, in addition to enhancing administration capacity and skills at the local level which has been proposed by CORDIS (2022), more targeted allocation at the regional level could also possibly help the CEE countries which lag behind Western fulfillment of the EU's climate and energy goals.

For the remaining (control) variables, we observe a statistically significant positive relationship between human capital in R&D, unemployment, and the EU funds expenditure. The EU funds seem to be implemented in areas with higher levels of human capital in R&D which can suggest that human capital is a prerequisite for investment in the low-carbon economy. In line with Cappelen et al. (2003), our assumption about the EU funds to less developed regions in terms of higher unemployment (columns (V), (VI), and (VIII)) has been confirmed as well. On the other hand, a decrease in the average population in 2014–20 (columns (III)–(VIII)) has been associated with an increase of EU funds to a low-carbon economy, i.e., more populated regions do not necessarily receive a higher portion of the EU funds.

While looking at spatial model estimations, the results regarding the direct effects of the EU funds' determinants remain qualitatively similar and thus, robust. The direction of the indirect (spillover) effects, i.e., effects related to the lagged explanatory variables is the same for the SLX model and SDEM model estimation (columns (VII)–(VIII)), however, a statistical significance of the indirect effect of population and GDP per capita has been confirmed only for SDEM, for which this result should be taken with caution. This might be related to examined spatial scale; as Smit et al. (2015) state, the reduced ability to identify the spillover effects might be related to the relatively high NUTS 2 level (which has been selected due to the data availability) since the spillover effects can be formed within their boundaries, at a lower scale. Regardless of that, the spatial model estimations confirm a non-statistically significant relationship between carbon emissions and EU funds (columns (VII)–(VIII)) to the low-carbon economy in the NUTS2 CEE regions.

CONCLUSION

Over the past decades, the EU takes steps towards mitigating the effects of climate change, a reduction of carbon emissions, with a recent target of being the first carbon-neutral continent. The EU Cohesion Policy plays a crucial role in achieving this goal by providing funding for the low-carbon economy and related climate actions.

Since the European Commission does not allocate EU funds directly to the regions with high climate needs, the aim of this paper was to investigate whether discrepancies between the regions' needs and funding did not appear in the sample of NUTS 2 regions in Central and Eastern Europe within the programming period 2014–20. We contribute to the empirical strand of this literature by providing regional evidence capturing the within-country heterogeneity in the CEE countries, but also considering spatial aspects of the EU funds through estimation of the spatial econometric models. To the best of our knowledge, such an approach has not yet been used in this context.

While we detect spatial dependence in the EU funding on the low-carbon economy in 2014–20, which is in line with the existing empirical literature (see, e.g., Smit et al., 2015; Antunes et al., 2020; Scotti, Flori and Pammolli, 2022), the non-spatial and spatial model estimations do not confirm a statistically significant positive relationship between a climate need proxied by carbon emissions in 2013 and the EU funds to a low-carbon economy in the programming period 2014–20. Our results, therefore, suggest that the EU funds with the low-carbon thematic objective have not been primarily spent in the regions with the highest carbon emissions prior to the examined programming period. This evidence can be considered as a part of the criticism of the Cohesion Policy in the environmental field as in Liobikiene and Mandravickaite (2016), or Dilba et al. (2016).

Since the mismatch between the spending strategies and development needs may be also linked with the expected effects of the EU funds, it would be appropriate to avoid this scenario from the point of view of effectiveness. At the same time, the presented analysis does not indicate misallocation as the cause of the overall inefficiency of the Cohesion Policy, rather it raises questions as to whether the given situation could not be prevented in the following programming periods. One of the possibilities may lie in the increasing awareness and necessary technical assistance for the beneficiaries, which could indirectly boost the demand and competition for such targeted EU support. This is important, especially in the CEE region which lags behind Western Europe in fulfilling the EU's climate and energy goals and is still dependent on energy-intensive industries.

As we do not detect robust spillover effects while considering spatial models, a lower granularity of data which could reveal broader spillover effects might be used in further work. Expansion to multiple thematic objectives and regions within the EU might be subject to our future research as well.

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ANNEX

Table A1 Variables description and data sources

Variable	Description	Source
EUfunds_carbon	Location data on a sum of total eligible expenditure for projects with the thematic objective low-carbon economy mapped to NUTS 2 regions, %GDP	European Commission
CO_2	Carbon dioxide emissions spatial point data (longitude and latitude coordinates) joined to NUTS 2 polygons, in ton substance	EDGAR, Eurostat
R&D	R&D personnel and researchers, the percentage of total employment (numerator in full-time equivalent)	Eurostat
Pop	Total population on 1 January, total sex, total age class, number	Eurostat
Area	Total area, square kilometer	Eurostat
Unemp	unemployment, from 15 to 74 years, thousand persons	Eurostat
GDPpc	GDP in Purchasing power standard (PPS, EU27 from 2020), per inhabitant	Eurostat

Source: Own elaboration based on data from EDGAR, the European Commission and Eurostat

Table A2 List of considered NUTS 2 regions

Code	Name	Country	Code	Name	Country
BG31	Severozapaden	Bulgaria	PL22	Slaskie	Poland
BG32	Severen tsentralen	Bulgaria	PL41	Wielkopolskie	Poland
BG33	Severoiztochen	Bulgaria	PL42	Zachodniopomorskie	Poland

Table A2 (continuation)

Code	Name	Country	Code	Name	Country
BG34	Yugoiztochen	Bulgaria	PL43	Lubuskie	Poland
BG41	Yugozapaden	Bulgaria	PL51	Dolnoslaskie	Poland
BG42	Yuzhen tsentralen	Bulgaria	PL52	Opolskie	Poland
CZ01	Praha	Czechia	PL61	Kujawsko-Pomorskie	Poland
CZ02	Strední Cechy	Czechia	PL62	Warminsko-Mazurskie	Poland
CZ03	Jihozápad	Czechia	PL63	Pomorskie	Poland
CZ04	Severozápad	Czechia	PL71	Lódzkie	Poland
CZ05	Severovýchod	Czechia	PL72	Swietokrzyskie	Poland
CZ06	Jihovýchod	Czechia	PL81	Lubelskie	Poland
CZ07	Strední Morava	Czechia	PL82	Podkarpackie	Poland
CZ08	Moravskoslezsko	Czechia	PL84	Podlaskie	Poland
EE00	Eesti	Estonia	PL91	Warszawski stoleczny	Poland
HR02	Panonska Hrvatska	Croatia	PL92	Mazowiecki regionalny	Poland
HR03	Jadranska Hrvatska	Croatia	RO11	Nord-Vest	Romania
HR05	Grad Zagreb	Croatia	RO12	Centru	Romania
HR06	Sjeverna Hrvatska	Croatia	RO21	Nord-Est	Romania
LV00	Latvija	Latvia	RO22	Sud-Est	Romania
LT01	Sostines regionas	Lithuania	RO31	Sud - Muntenia	Romania
LT02	Vidurio ir vakaru Lietuvos regionas	Lithuania	RO32	Bucuresti - Ilfov	Romania
HU11	Budapest	Hungary	RO41	Sud-Vest Oltenia	Romania
HU12	Pest	Hungary	RO42	Vest	Romania
HU21	Közép-Dunántúl	Hungary	SI03	Vzhodna Slovenija	Slovenia
HU22	Nyugat-Dunántúl	Hungary	SI04	Zahodna Slovenija	Slovenia
HU23	Dél-Dunántúl	Hungary	SK01	Bratislavský kraj	Slovakia
HU31	Észak-Magyarország	Hungary	SK02	Západné Slovensko	Slovakia
HU32	Észak-Alföld	Hungary	SK03	Stredné Slovensko	Slovakia
HU33	Dél-Alföld	Hungary	SK04	Východné Slovensko	Slovakia
PL21	Malopolskie	Poland			

Source: Own elaboration