Journal of Regional Science

WILEY

JOURNAL OF REGIONAL SCIENCE

RESEARCH ARTICLE OPEN ACCESS

The Long-term Socioeconomic Impacts of Renewable Energy Deployment: Lessons From Case Studies in European Rural Regions

Álvaro García-Riazuelo | Rosa Duarte | Cristina Sarasa

Department of Economic Analysis, Agrifood Institute of Aragon (IA2), Zaragoza, Spain

Correspondence: Álvaro García-Riazuelo (alvgarcia@unizar.es)

Received: 4 June 2024 | **Revised:** 24 March 2025 | **Accepted:** 26 March 2025

Funding: Financial support was provided by the Gobierno de Aragón. This work has been partially supported by projects PID2022-14001OB-100 financed by MICIU/AEI/10.13039/501100011033 and FEDER, UE and the Consolidated research group S40_23R of the Government of Aragon (Research Group 'Growth, Demand and Natural Resources'). Álvaro García-Riazuelo also acknowledges the support received by the Program Predoctoral Fellowships 2020-2024, by Government of Aragon. Rosa Duarte, Álvaro García and Cristina Sarasa also acknowledge the financial support by the European Union (PANTHEON/ Pathways to (wards) carbon neutrality for climate, environment, health and socio-economic co-benefits (HORIZON EUROPE Grant Agreement 101137905). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Keywords: energy transition | renewable energy | rural development | synthetic control method | territorial integration

ABSTRACT

The new environmental and geopolitical situation has led to the need for a change in the current energy model. The infrastructures associated with renewable energies may represent an opportunity for economic growth, employment generation, and population recovery in rural territories. This study evaluates the retrospective long-term impacts that renewable energy installations have had on several rural regions in Europe. To that end, we develop a novel database on the annual installed capacity of renewables for European NUTS2 regions. This includes data on wind and photovoltaic energy, allowing us to capture both the scale and growth of renewable energy infrastructure over time in European regions. The data set spans multiple decades. Finally, we evaluate the socioeconomic effects these installations have on Europe's renewable energy capacity intensive rural regions analysing the different intra- and interregional impacts, using the Synthetic Control Method.

1 | Introduction

The growing political, social, and environmental pressures to fight against climate change underscore the imperative for a shift in the existing energy model. This transition stands as a pivotal component in the decarbonization journey of developed economies (Baeyens and Goffin 2015; UN 2016). Within the European Union (EU), the emphasis on renewable energies has intensified. This focus aligns with environmental goals that advocate for an energy paradigm shift, further underscored by the imperative to diminish energy reliance on nations that may pose political, social, or economic instability risks due to the strategic importance of this resource (European Commission, 2022).

Thus, the EU has been at the forefront of global efforts to reduce carbon emissions and promote renewable energy, setting ambitious targets for its member states. More specifically, Europe's climate targets state to reduce emissions by 55% by 2030 relative to 1990 levels and achieving climate neutrality by 2050 (European Commission 2019).

To meet these targets, the recent European agreements on renewable energy on March 2023 (Renewable Energy Directive, EU/2018/2001) have set a provisional target of 45% of the energy mix to come from renewable energy sources by 2030.

Overall, the EU's regulatory framework accompanying the green transition and the shift to renewable energies reflects a comprehensive and integrated approach, addressing not only the environmental benefits but also the economic and social aspects of the energy transition. With regard to socioeconomic aspects, reference is made to the importance of generating economic growth and new jobs, to ensure a socially just energy transition (European Commission 2019). However, the implementation of these regulations largely varies across countries and regions, and ongoing efforts are needed to ensure that the EU achieves its renewable energy targets in a fair and equitable way.

In other words, the development of renewable energies plays a fundamental role in changing the energy model of most developed countries to meet these environmental and geopolitical objectives proposed by national and international institutions. This development has also been conceived in the EU across different governmental scales—international, national, and local—as a pivotal strategy to combat depopulation. This commitment is evidenced by substantial financial investments, such as the Just Transition Fund and the European Climate Pact. In essence, achieving sustainable and inclusive development requires aligning economic, social, and environmental objectives, as highlighted by (Roberts 2003), being crucial to ensure a fair energy transition process in the regions and areas where these transitions occur.

In fact, in the rural context, given the climatic and territorial characteristics, the deployment of renewables has been often seen as a key strategy to mobilise investments in mature economies lacking other dynamic projects that, in addition to generating employment, may encourage the expectations of their rural society (OECD 2012). Thus, these could become a new catalyst for local economic development, as these emerging, dynamic, and technological advanced activities sometimes arrive at territories with a recent history of industrial restructuring and closure of coal mines. Rural territories with poorly diversified economies that are highly dependent on coal-thermoelectric binomial[1] have felt excluded from the process of economic development, with the political and social consequences that this may entail (see Dijkstra et al. 2020; Rodríguez-Pose 2018).

However, the deployment of renewable energies also potentially involves negative externalities in the territories where they are located (Bielecki et al. 2020; Dröes and Koster 2016; Mattmann et al. 2016; Zerrahn 2017). For instance, van der Horst (2007) and Batel (2020) conclude that, due to the affected population, these territories assume the tangible costs of the energy transition, but not the benefits, which are more diffuse in space and time[2].

In the literature, most studies focused on analysing the economic impacts that the energy transition has on employment and wealth at a global level (Batini et al. 2022; IRENA 2021; Lehr et al. 2012). However, the spatial distribution of these impacts has received little attention (Brown et al. 2012; Costa and Veiga 2021; [name deleted to maintain anonymity in the review process]). Moreover, there is limited analysis of the compatibility of environmental and socioeconomic objectives of renewables in the literature (Colli 2020; Jenkins et al. 2017; Perez-Sindin et al. 2022; Wang and Lo 2021). These studies focus on the idea that renewables do not have a dynamizing potential per se, but that the idiosyncrasies of the territories must be taken into account. International institutions (Kerr et al. 2022; OECD 2012) claim the need to carry out this type of analysis linked to the concept of a just energy transition.

In this context, this paper aims to contribute to the debate on the nature and spatial distribution of socioeconomic impacts of the current renewable energy deployment process, particularly on the compatibility of the social (employment) and economic objectives in the territories where renewable energies are installed. Furthermore, this paper examines the impact each type of renewable source generates, the influence of the territorial differences, and how the management in the expansion of renewables affects the socioeconomic results of the territory.

The equitable distribution of resources and services in space is a basic right, as a definition of the concept of spatial justice (Soja 2010). This spatial justice approach is the conceptual framework of the European Union's territorial cohesion policy, whose objectives are convergence and reduction of territorial inequalities (Madanipour et al. 2022; Weck et al. 2022). Recently, literature has giving importance to the concept of spatial justice that is environmentally sustainable (Demeterova 2024).

In this line, this study emphasises the concept of a spatially just energy transition (Bouzarovski and Simcock 2017; Garvey et al. 2022). Although normative in nature, literature on spatially just energy transition has attempted to analyse the fair distribution of the benefits and burdens of this transition in space (Lehmann et al. 2024; Sasse and Trutnevyte 2020). Similarly, the European Green Deal seeks to assist regions by encouraging the development of renewable energies for the generation of wealth and new green jobs so that "no person or place is left behind" to achieve a Just transition (European Commission 2019). Based on this framework, this paper analyses the spatial distribution of the benefits and burdens that the development of renewable energies has had on rural areas in terms of employment, population, and wealth using a number of case studies from European regions.

Finally, we also aim to contribute to the debate on the so-called natural resource curse or the Dutch curse (see Corden 1984; Hosoda 2016; van Wijnbergen 1984), exploring whether there could be a new "curse" related to the abundance of natural resources such as wind and sun (Leonard et al. 2022; Månsson 2015). The potential benefits of the energy transition are often taken for granted. However, while the potential benefits of the energy transition are frequently acknowledged, it's essential to recognize that at the local level—especially in rural areas where renewable energy infrastructure is installed— such benefits are not invariably assured.

Existing literature has endeavoured to examine the potential synergies between the development of renewable energy and rural progress (Clausen and Rudolph 2020), finding that these may end up becoming peripheral energy zones, thereby not effectively influencing the energy transition's impact on rural development (O'Sullivan et al. 2020). Therefore, this paper seeks to empirically assess whether the development of renewable energies has positively or negatively affected the development of these rural areas. For this purpose, and as a proxy of rural development, we will analyse the impacts on wealth, population, and employment. As highlighted by these scholars, there exists a possibility that certain territories lack the infrastructure and mechanisms necessary to effectively harness and assimilate these renewable energy investments, consequently limiting their potential to stimulate economic growth, foster employment, and therefore population. However, it appears evident that negative effects manifest at the local level (Zerrahn 2017). Therefore, in this paper, we raise the question of whether the potential positive effects can be overshadowed by the pronounced negative effects at the local level, thus reiterating the possibility of a natural resource curse.

More specifically, this paper analyses the long-term socioeconomic impacts that the installation of renewable energies has had on European rural regions. To do this, we use a robust approach based on the Synthetic Control Method (SCM). This method studies the potential effects of some kind of intervention. Thus, this methodology allows us in this paper to analyse the retrospective long-term socioeconomic impacts of the development of renewable energy. Originally, this method was applied to the analysis of public policies and legal interventions (Abadie et al. 2010; Abadie and Gardeazabal 2003), but in recent years this methodology has been established as one of the major tools for the evaluation of causal effects (Athey and Imbens 2017). The traditional method has been extended with a more novel approach, Synthetic Difference in Differences (Arkhangelsky et al. 2021).

Empirically, our analysis exploits a novel database that includes information on the annual installed capacity of renewables at NUTS 2 disaggregation level for the European regions, describing the period in which these regions started to operate and the technology (wind or photovoltaic). The construction of this comprehensive database is also an additional value added of this paper. This is the first study using these data for the evaluation of the installation of renewable energies. With this approach, the following questions linked to sustainable rural development are addressed:

1. Has the development of renewable energies channelled into long-term positive socioeconomic impacts in the European rural territory where they are installed?
2. Specifically, and as a proxy for potential socioeconomic impacts, what impact did these infrastructures have on population, income, and employment?
3. Are the development of renewable energies in rural regions a key element that stopped or moderated population decline?

In particular, we focus our analysis on the following selected European regions: Centro in Portugal, Galicia in Spain, Niederbayern and Sachsen-Anhalt in Germany, and Sud-Est in Romania. These rural European regions are currently in the first percentile of renewable energy capacity intensity (MW/km2), and more interestingly, they developed these energies since the beginning of the 21st century to analyse their effects in the long term. Once the impacts at NUTS2 level have been analysed, the analysis at NUTS3 level is carried out to analyse how these impacts are distributed intra-regionally, as it is possible that the socioeconomic effects of the installation of renewable energies differ significantly within the same region. With this multilevel analysis of different territorial scales, we will have more precise evidence on the potential impacts of renewable energies at the territorial level.

To the best of our knowledge, only a few studies have analysed the long-term territorial impact of the deployment of wind farms on employment (Brown et al. 2012; Costa and Veiga 2021; Fabra et al. 2022; Hartley et al. 2015). Additionally, to the best of our knowledge, this is the first study that analysed the long-term effects on the population, GDP per capita, and employment using as a case studies several European rural regions.

The case study of the European NUTS2 rural regions reveals that the previous economic and social (employment) structure, measured in terms of wealth and population density, is important for the economic and social performance of these regions. In turn, the way in which the integration of renewable energies is managed (size of installation, installed technology, and form of management) in the territory also seems to be important in the potential positive impact of renewable energy development in the regions analysed. Our findings also show that renewable energy will not stop depopulation. This heterogeneity of results at interregional level (NUTS2) is also observed at intra-regional level (NUTS3) as the impacts are not homogeneously distributed intra-regionally. Intra-regionally, the positive employment and population impacts are concentrated in the wealthier and more densely populated NUTS3 regions.

The rest of the paper is structured as follows. Section 2 contextualises the paper and Section 3 describes the data and methodology; Section 4 presents the results; Section 5 discusses the main findings; and Section 6 describes the main conclusions.

2 | Background: Renewable Energy In Rural Regions

Most renewable energy technologies are in rural areas (Mulvaney et al. 2013; OECD 2012) due to the ease of implementing these installations and the availability of natural resources. Some scholars acknowledge that the capacity of renewable energy investments to reverse dynamics is potentially greater in these areas than in urban areas, with different economic and social dynamics (Clausen and Rudolph 2020). In addition to the European energy and environmental strategy mentioned above, there is regional policy to promote rural development and slow down depopulation (ENRD 2022; European Commission 2021). In consequence, to analyze the compatibility of these policies at the European level becomes relevant.

According to IRENA (International Renewable Energy Agency 2020), the installed capacity of photovoltaic energy would generate an investment of 3.56 million euros per MW and 1.48 million euros per MW for wind energy in 2010[3]. Thus, investment in renewable energy can have the capacity to transform the economic and social structure of rural areas depending on the different socioeconomic factors in these areas (del Río and Burguillo 2009). However, there is limited literature based on the opportunity that the investment in renewable energies can create in rural development (Copena and Simón 2018; Munday et al. 2011), the capacity to transform its productive structure (Slattery et al. 2011), in these areas that are also undergoing a process of reconversion from coal to renewable sources (Collins et al. 2012; OECD 2021).

Renewable energies have the potential to transform the economic and industrial landscape of rural areas, peripheral and lagging-behind regions making them more dynamic and thus generating wealth, employment, and population (Coenen et al. 2021; Grillitsch and Hansen 2019). A green and clean industry can be created around these installations, generating added value and employment in these areas (Clausen and Rudolph 2020). Thus, renewable energies can be a catalyst of endogenous resources to revitalise declining rural areas, as is explained in the report "Shrinking rural regions in Europe" (ESPON 2017). However, empirical evidence limits the potential and generalized nature of these results. Costa and Veiga 2021 and Fabra et al. 2022 only transitory local effects on employment, linked to the construction process of the installations. Brown et al. 2012 detected a slight impact on employment and wealth, while Hartley et al. 2015 found no impact on either variable. Mauritzen 2020 also discovered very modest results on rural wages. These limited results at local level open the debate on the possible existence of crowding out effects of investment in other economic sectors (Sardaro et al. 2019).

Less works studied the impacts on population, although obviously closely linked to the employment and wealth variables. Only one paper analyses these effects, from an empirical point of view, finding no significant effects on population ([name deleted to maintain anonymity in the review process]).

In the context of this literature, our paper benefits from prior works and go further into the analysis to evaluate the long-term effects of renewable infrastructures in rural European regions on the population, GDP per capita, and employment.

From the empirical point of view, we make use of Synthetic Control Method to analyse the long-term socioeconomic impacts of the development of wind and photovoltaic farms. This methodology is chosen because it is a causal analysis tool, ideal for analysing the potential effects of some kind of intervention or shock, in this case, the deployment of renewable energies. Unlike difference-in-differences and regression approaches, this method can take into account the effects of confounders affecting the variables under analysis. Using this approach, we can assess the causal effects of the installation of renewable energies. See Abadie 2021 for a discussion of the advantages of this methodology for the causal analysis.

This methodology has been widely used to study economic events. For instance, the seminal paper of Abadie and Gardeazabal (2003) applies this technique to analyse the economic impact of terrorism. The economic effects of other armed conflicts have also been analysed with this methodology (Horiuchi and Mayerson 2015; Montalvo 2011; Pinotti 2015). It was also used to analyse the economic effects of German reunification (Abadie et al. 2015) or entry into the European monetary union (Hope 2016). Moreover, it has been used in health economics (Cunningham and Shah 2018; DeAngelo and Hansen 2014; Lindo and Packham 2017) and labour economics (Dustmann et al. 2017; Gobillon and Magnac 2016; Kleven et al. 2013; Zou 2018). Additionally, the SCM was used to analyse the impact of different public policies on the environment. For example, it was used to analyse the impact of carbon taxation (Andersson 2019; Leroutier 2022; Runst and Thonipara 2020; Xiang and Lawley 2019), traffic decongestion (Green et al. 2020), and regulatory framework (Kim and Kim 2016). Interestingly, the synthetic control method was also used to analyse the economic effects of natural disasters (Cavallo et al. 2013) and the discovery of new sources of natural resources (Smith 2015). Similar to our study, the SCM was used to analyse the socioeconomic impacts of oil and gas extraction in several US states (Munasib and Rickman 2015; Rickman and Wang 2020), case regions of China (Hu et al. 2021), case of Italian NUTS 2 regions (Pellegrini et al. 2021), and the impacts of nuclear (Ando 2015) and hydropower at the local level (Catolico et al. 2021). Finally, [name deleted to maintain anonymity in the review process] analysed the socioeconomic impacts of wind energy using the SCM for one only county, in the region of Aragon (NUTS 2), in Spain.

This study presents a novel extension of the analysis with this method to the case of renewables at the European regional NUTS 2 level. This is the first study analysing the long-term effects of the development of renewable (wind and photovoltaic) infrastructures in rural regions on population, GDP per capita and employment for all European rural regions. Moreover, the analysis is extended at different spatial levels (NUTS 2 and NUTS 3). Finally, the Synthetic Differences in Differences method is used to test the robustness of the results.

3 | Data and Methodology

3.1 | Data and Selection Criteria

This study analyses the economic impacts of the renewable infrastructures built in *rural European regions*. For this purpose, a comprehensive and unique database on the annual installed capacity (in MW) of renewables in each region has been first developed; the database includes information from beginning of the development of renewable energy sources along with the main socioeconomic characteristics of the region. This database allows us to identify the technological options (wind and photovoltaic[4]), the starting operational period, and the annual installed capacity of 322 NUTS 2 regions (see Appendix A in the Supporting Information (SI onwords) for information on data set development). To construct this database, we integrated information from multiple sources, including Eurostat, national energy agencies, and regional statistical offices. This approach allowed us to ensure the data's accuracy, comparability, and granularity, essential for evaluating regional differences in renewable energy development. There is no public database with such information. Therefore, its exploitation provides a better ability to understand the energy transition at regional level.

To answer the questions raised, the analysis will focus on the long-term socioeconomic impacts of renewable energy installation in a group of rural regions in Europe. In particular, we are interested in analyse these effects in those rural regions with a high renewable capacity intensity and a long-term experience of renewable energy production. As mentioned above, the objective is to analyse these impacts in rural regions, since it is in these regions that renewable energy installations can have the largest impact, as discussed in the previous section.

To operationalize the analysis, i.e., to select the regions of interest (with these characteristics of rural, renewable capacity intensive and traditionally intensive (long-established track of renewable energy production), the following procedure has been implemented.

First, we identified the European regions classified as a rural region according to the EUROSAT definition (see Appendix B in SI for more details on the urban/rural classification). All NUTS 3 regions classified as urban, as well as NUTS 2 regions containing any NUTS 3 classified as urban, are excluded from the analysis.

Then these rural regions were classified according to their renewable energy capacity intensity. With the information from the database presented above, each region can be characterised according to its renewable energy capacity intensity (in terms of MW/km2). Figure 1 presents the capacity intensity of renewables installation for all European NUTS 2 level for the year 2019.

A region is classified as renewable capacity intensive if it is above the 75th percentile in both installed power (MW) and installed power per square kilometre in 2019 (following the percentile-based definition of Cavallo et al. 2013)[5]. The year 2019 is used as the benchmark year, as it is the latest year with available and complete information for the data presented above. Note that, as the energy transition (proxied in this case as installed capacity in MW) is a cumulative process, we select those regions that are currently most specialised in this type of energy deployment to be able to analyse the effect of this process. By focusing on the economic and social impact of energy infrastructures, in this case wind farms and photovoltaic parks, we are interested in their capacity. The higher the capacity, the

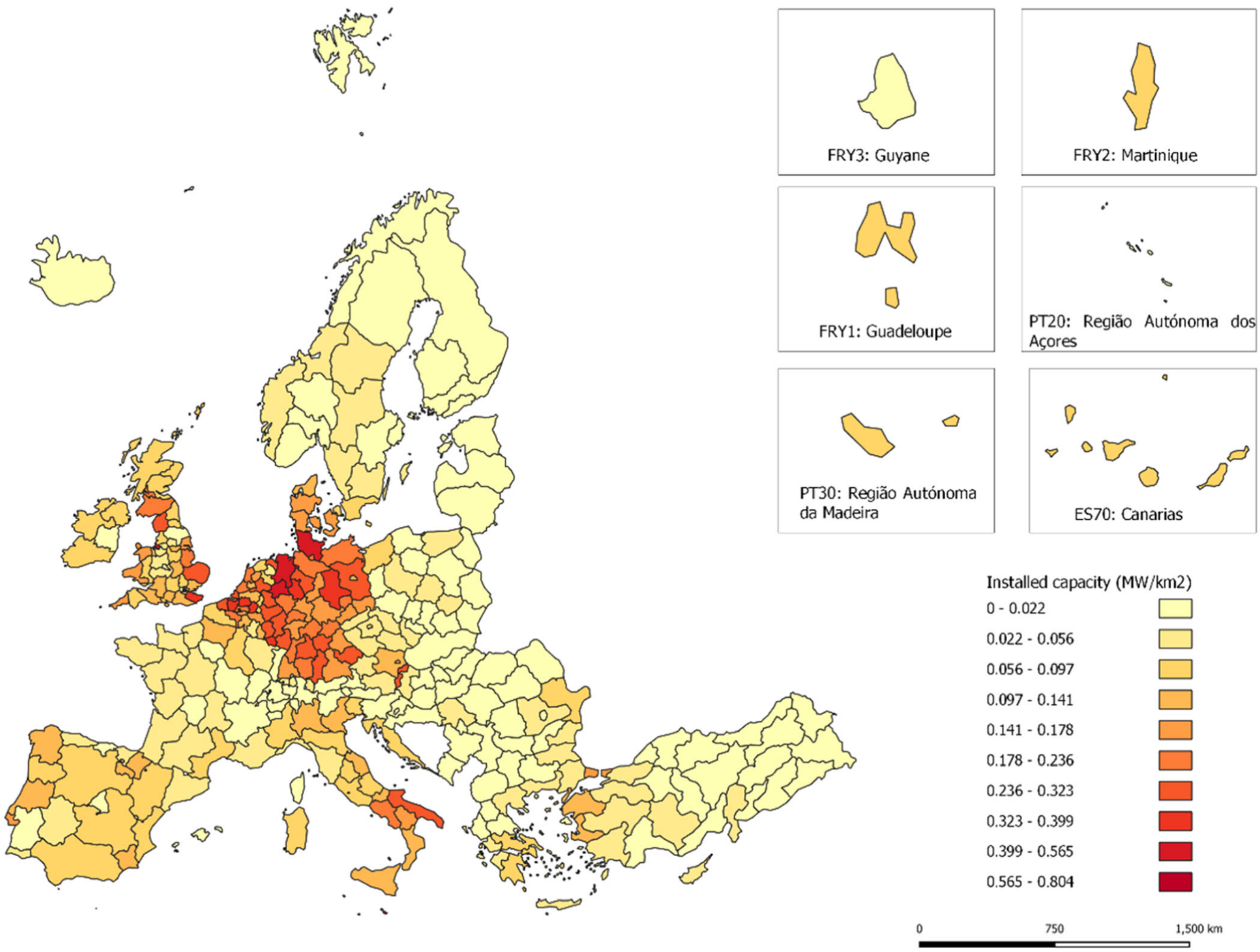

FIGURE 1 | Renewable energy installed capacity per km² in 2019. NUTS 2 regions. [Color figure can be viewed at wileyonlinelibrary.com]

greater the land use required (Perpiña Castillo et al. 2016) and therefore the greater the potential impacts.

Finally, among the regions classified as *renewable energy capacity intensive*, we select those *traditionally intensive*, i.e. those regions with a long-term track of renewable energy installation, that is, where the energy transition process started at the beginning of the century. As the aim of this paper is to analyse the impacts of this installation on the territory in the long term, our target regions are those that undergone the installation process since the beginning of the 21st century. As result, the only regions that meet these characteristics and in consequence are the selected ones for analysis are Sud-Est in Romania (RO22), Sachsen-Anhalt (DEE0) and Niederbayern (DE22) in Germany, Centro (PT16) in Portugal, and Galicia (ES11) in Spain, and their respective NUTS 3 regions. Note that some other regions have recently become intensive in renewable energy capacities. However, in this case, we cannot yet analyse the potential impacts from a retrospective point of view.

Figure 2 shows the trajectory of renewable energy expansion in the five regions mentioned. The trajectory is very similar for all of them; started at the beginning of the 21st century, peaked between 2007 and 2010, and were stagnant thereafter. Only in recent years they started to move back in. However, Sachsen-Anhalt (DEE0) was an exception, as this region's trajectory was continuous over time.

3.2 | Methodology

This study used the synthetic control method to analyse the long-term effects that the development of renewable infrastructures in rural regions had on three main socioeconomic variables (population, GDP per capita, and employment). This methodology was initially developed by Abadie and Gardeazabal (2003). It was further developed by Abadie et al. (2010, 2015). The objective is to evaluate the impacts, such as the causality of any type of intervention on the treatment units (countries, regions, municipalities, etc.).

Recently, the work of Abadie (2021) summarised this methodology and the extensions made over the last 20 years. This section explains the logic of this methodology (see Abadie (2021); Abadie et al. (2010) for more technical details).

Let us consider $J+1$ units with $j = 1, 2,..., J+1$. For simplicity, the first unit ($j = 1$) can be set as the treated unit—the unit for which the impacts of an intervention are being analysed. The "control group" consists of the set of potential comparable units ($j = 2,..., J+1$) where the intervention has not been implemented. All the units are observed for time periods $t = 1, 2,..., T$. Let us divide the sample period into the pre-intervention (1, 2,..., T_0) and post-intervention period ($T_0+1, T_0+2, ..., T$). Therefore, for each unit j, in period t, the variable to be analysed is Y_{jt}. In turn, for each unit j there is a set k of predictors of the outcome, $X_{1j},...,X_{kj}$, where it can also include the pre-intervention values of Y_{jt}. The k x1 vectors $X_1,..., X_{j+1}$ contain the values of the predictor variables for the units $j = 1, 2,..., J+1$. As a result, the k x J matrix, $X_0 = [X_2...X_{J+1}]$, contains the predictor variables for the J units in the control group. It also defines a (T_0 x 1) vector, $R = (r_1,..., r_{T_0})'$, that denotes some linear combination of pre-intervention outcomes: $\bar{Y}_i^r = \sum_{s=1}^{T_0} r_s Y_{is}$.

It can also define Y_{jt}^N as the potential variable to be analysed without intervention, such as the variable to be estimated. Y_{1t}^I, is the real path of the variable of interest, for the unit affected by the intervention ($j = 1$) in the post-intervention period ($t > T_0$). Consequently, the effect of the intervention on the variable of interest for the treated unit in period t (with $t > T_0$) is:

$$\alpha_{1t} = Y_{1t}^I - Y_{1t}^N \tag{1}$$

This methodology aims to estimate Y_{1t}^N for $t > T_0$, what the outcome of the variable would be in the absence of intervention. In short, since Y_{1t}^I is observable, it is necessary to estimate Y_{1t}^N, the counterfactual outcome, to estimate the effects of the intervention.

Traditionally in the literature, to solve this problem, to reproduce Y_{1t}^N, a unit of the control group that is as similar as possible to the one treated at the time before the intervention is used as a counterfactual (B. D. Card and Krueger 2000; D. Card 1990). In practice it is difficult to find a single control unit that resembles the treatment unit in all characteristics. Therefore, to solve this problem, the synthetic control method uses a combination of control units that are as close as possible to the treatment unit in the characteristics at the time before the intervention. That is, the synthetic control group is defined as a weighted average of the control units. Technically, it is represented by the following J x 1 vector of weights $W = (w_2,..., w_{j+1})'$. Each W then represents one particular weighted average of control units and therefore one possible synthetic control unit.

Once these weights are obtained, the synthetic control estimators of Y_{1t}^N and α_{1t} are:

$$\hat{Y}_{1t}^N = \sum_{j=2}^{J+1} w_j Y_{jt}, \tag{2}$$

$$\hat{\alpha}_{1t} = Y_{1t} - \hat{Y}_{1t}^N \tag{3}$$

To avoid extrapolation, the weights will always satisfy the following two conditions: $w_j \geq 0$ for $j = 2,..., J+1$ and $w_2 + ... + w_{J+1} = 1$ (see Abadie (2021) for more details).

Abadie et al. (2010) and Abadie and Gardeazabal (2003) propose to choose the weights ($w_2,...,w_{J+1}$) that best reproduce the values of the predictor variables of the treated unit at the time before the intervention. Given a set of non-negative constants, $v_1,...v_k$, this means to choose the weights, $W^* = (w_2^*,..., w_{j+1}^*)'$ that minimizes:

$$\|X_1 - X_0 W\| = \left(\sum_{h=1}^{k} v_h \quad (X_{h1} - w_2 X_{h2} - ... - w_{j+1} X_{hj+1})^2 \right)^{\frac{1}{2}} \tag{4}$$

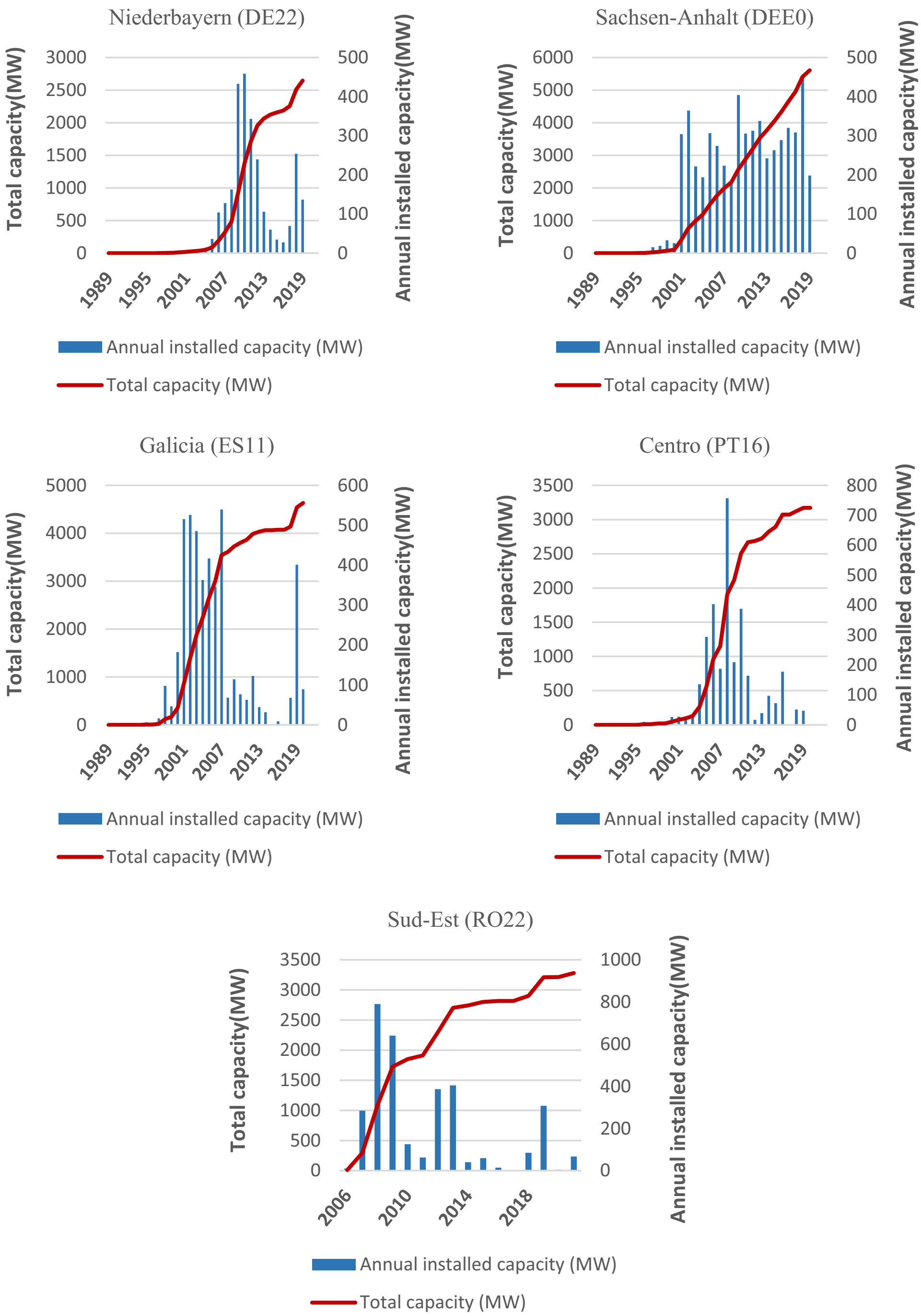

FIGURE 2 | Annual and cumulative installed capacity in renewable energies. [Color figure can be viewed at wileyonlinelibrary.com]

Subject to these two conditions: $w_j \geq 0$ for $j = 2, ..., J + 1$ and $w_2 + ... + w_{J+1} = 1$. Then, the estimated treatment effect for the treated unit at time $t = T_0 + 1, ..., T$ is

$$\hat{Y}_{1t}^{N} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \tag{5}$$

The constants $v_1, ... v_k$ in (4) reflect the relative importance of the model by reproducing the values of each of the k predictor variables for the treated unit, $X_{11}, ..., X_{k1}$. Moreover, it is suggested to choose a symmetrical, semi-positive $(k \ x \ k)$ matrix $V^* = (v_1^*, ... v_k^*)$, such that the synthetic control $W(V^*)$ minimizes the mean squared prediction error (MSPE) of this synthetic control with respect to Y_{1t}^N before the intervention:

$$\sum_{t \in \mathrm{T}_0} (Y_{1t} - w_2(V^*) Y_{2t} - ... - w_{j+1}(V^*) Y_{j+1t})^2, \quad \text{with} \quad \mathrm{T}_0 \subseteq \{1, 2, ..., T_0\}. \tag{6}$$

In definitive, a nested optimization problem is solved that minimizes Equation (6), for $W^*(\mathrm{V})$ subject to Equation (5). In short, once the minimisation process has been carried out (if our model works correctly) it will obtain that $Y_{1t} \approx w_2^*(V^*) Y_{2t} + ... + w_{j+1}^*(V^*) Y_{j+1t}$ for $t = 1, 2, ..., T_0$, and $X_1 \approx X_0 W^*$.

In sum, this methodology generates a synthetic control group (*counterfactual)* that is as similar as possible to our treatment unit at the time before the intervention, both for the variable under study and possible predictor variables at the time before the intervention, so the differences observed between the evolution of the treatment unit and the counterfactual after the intervention period can be caused by the specific intervention analysed.

3.3 | Robustness Analysis

To complete the previous analysis, Abadie et al. (2010) propose several inference methods to check whether the causal results obtained are significant. This procedure uses an inference method based on permutation methods (Bertrand et al. 2004). First, they consider what is known as "placebos in space". In this test the effects analysis is reassigned to all units in the control group. Therefore, if our synthetic control works correctly and our model can reproduce our units, then it would be expected that there would be no effect on the units in the control group. If the impacts found for our treatment units are extremely higher than the distribution of placebos in space, then it can be concluded that our impacts are significant.

Before the intervention, the trajectories of the variables studied may not be similar for all the units in the control group—this may distort the robustness analysis. For this reason, Abadie et al. (2010) propose a statistical test that measures the ratio of post-intervention fit relative to pre-intervention fit.

$$\text{For} \quad 0 \leq t_1 \leq t_2 \leq T \quad \text{and} \quad j = \{1, \ldots, J+1\}, \text{let}$$

$$R_j(t_1,t_2) = \left(\frac{1}{t_2 - t_1 + 1} \sum_{t=t_1}^{t_2} \left(Y_{jt} - \hat{Y}_{jt}^N \right)^2 \right)^{1/2} \tag{7}$$

Where $\hat{Y}_{jt}^N$ is the outcome of the variable of study on period t produced by a synthetic control when unit j is coded as treated unit and using all J units as a control group. This is the same as the root mean squared prediction error (RMSPE) of the synthetic control estimator for unit j and time periods $t_1, \ldots, t_2$. Therefore, the ratio between post and pre-intervention RMSPE for each unit j is

$$r_j = \frac{R_j(T_0 + 1, T)}{R_j(1, T_0)} \tag{8}$$

This indicator measures the quality of the fit of the synthetic estimator in the post-intervention period relative to the quality of the fit in the pre-intervention period.

With this information, it can be calculated a p-value for the significance of the estimated effect, based on the permutation distribution of r_j,

$$p = \frac{1}{J+1} \sum_{j=1}^{J+1} I_+(r_j - r_1), \tag{9}$$

Where $I_+(\bullet)$ is an indicator function that returns one for non-negative arguments or otherwise, zero. It is common in the literature not to use the calculation of the p-value for those units of the control group with an $R_j(1, T_0)$ extremely larger than $R_1(1, T_0)$.

Under the same logic, the "placebos in space" are proposed. In this case, the permutation is carried out for the year of intervention. If the year of intervention is reassigned years back from when it occurred, and our synthetic control works correctly then no significant effects should be expected since nothing relevant occurred at this new time of intervention[6].

These authors also propose a test known as the "leave-one-out" test, which is also implemented in our analysis, to check the robustness of the results to synthetic control group regions. As already mentioned, the synthetic control method offers a W^* matrix, which usually has very few values different from zero (sparse). Therefore, it is necessary to assess the influence that each unit of the synthetic control group has on the results obtained. The procedure consists of re-running the analysis each time excluding one unit that is part of the counterfactual and if the results do not change, the estimated results will be robust.

Finally, to make the results more robust, we also estimate the possible effects by one of the most recent advances in this methodology, the Synthetic Difference in Difference (SDID) (see Arkhangelsky et al. 2021 for technical details). The idea behind this methodology is to merge the SCM explained above with the classical Difference in Difference model (DID), which brings in strengths from both the DID and SCM methods, making the estimator more robust. In particular, the SDID method is more flexible than the SCM, since it does not require perfect pre-intervention matching, as well as controlling for unobserved heterogeneity of possible confounders. However, the SDID requires the existence of the parallel trend assumption, as well as less transparency and interpretability of the synthetic control group (Clarke et al. 2023). Similar results are expected to be found in both cases, see below in Section 4.

3.4 | Case Studies and Empirical Approach

In this study, the causal effects of renewable energy infrastructure deployment on the three variables are analysed: population, GDP per capita, and employment in rural European areas.

The treatment units are composed of the five European regions; Centro (PT16) in Portugal, Galicia (ES11) in Spain, Niederbayern (DE22) and Sachsen-Anhalt (DEE0) in Germany, and Sud-Est (RO22) in Romania. The control group consists of 77 European rural regions[7], where the installation of renewables is residual both in terms of absolute (MW) and relative capacity (MW/km2) in 2019, latest year for which information is available. To assess the effects of the installation of renewable technologies, the potential synthetic control units should not be exposed to the intervention to avoid possible biases. The treatment group extends to all NUTS 3 regions that comprise these

NUTS 2 regions to assess potential intra- and interregional heterogeneous impacts.

One of the key aspects of the Synthetic Control Method (SCM) is the selection of the intervention period. In this regard, we follow the approach of Munasib and Rickman (2015) for case studies related to the economic impacts of energy activities. The year of intervention assigned to carry out the analysis is the year before the installation of renewable energies in each region. In addition, it is often the case that there is a time lag between the implementation of the energy policy and the installation of renewable energies. In turn, there is a time difference between the construction phase and the commissioning of the installation. For these reasons, it seems sensible to choose this year as the year of intervention, since the effects should start to be observed from that year onwards. Each case study is analysed individually. As will be shown below, each region has a different intervention year, reflecting the varied timelines for the introduction of renewable energy installations across regions. This approach allows us to account for regional differences in the timing of renewable energy adoption and to examine the impacts in relation to the specific year when significant installations began in each area. Furthermore, the analysis also allows us to examine different installation patterns, as shown in Figure 2, where each case study analyzed displays a distinct pattern, both in terms of speed and added capacity. This allows us to analyze an additional heterogeneous component, which may be of interest for the analysis of our case studies.

As mentioned above, our synthetic control should reproduce as well as possible our treatment regions (see Ferman et al. [2020] for more information on the choice of predictor variables in the SCM). For this purpose, information from EUROSTAT (2021) and the ARDECO database (2021) is used. Specifically, a counterfactual will be found as close as possible to the following characteristics: Investment per GDP[8] (1994–2021) (Driffield and Hughes 2003; Pavlínek 2004; Rodríguez-Pose* and Fratesi† 2004), population density (1990–2021) (Sterlacchini 2008; Zheng 2007), unemployment rate (2000–2020) (Giannakis and Bruggeman 2017; Palombi et al. 2015), % population with tertiary education (2000–2020) (Gennaioli et al. 2013; Sterlacchini 2008), and sectoral productive structure measured as percentage of value added generated by each sector (1996–2018) (Pires Manso et al. 2015).

Additionally, as a novelty for this methodology, we estimate demand-weighted backward and forward linkages indicators for the energy sector[9] for the 2000–2010 period using a multiregional input-output model, which is developed from the global input-output table with regional detail (EUREGIO) (Thissen et al. 2018)[10]. These linkage indicators provide information on the economic interdependencies of the energy sector in each region. Regions with strong backward and forward linkages for the energy sector play an important role in the regional development strategy, which can be seen as a key sector for the provision of inputs and output utilisation as inputs in another sector.

The pre-intervention means of the population (1990–2021), GDP per capita (1991–2021), and employment (1995–2021) (following Lan et al. [2021]) are also used for the minimization process. To satisfy the convex hull condition and following the idea of Abadie (2021), the variables under study are transformed as follows: GDP per capita/1000; Population/10000 and employment is relativised for the base year (1995). The inclusion of all these variables in the model is intended to minimise the risk of potential confounders in the explanations for observed outcomes. Placebos in space will help to analyse whether the choice of these variables is correct, since if there are many potential confounders, very large effects should be found in regions not affected by the installation of renewable energy.

Finally, the W^* matrices obtained for each case study are presented (see Tables SI.3 to SI.7 in the Appendix D of the SI). Previous Table SI.2 of the SI presents the average characteristics of the selected regions at the time before the intervention, and those of the synthetic control are displayed. As can be seen in all the case studies, the counterfactual represents the economic and social structure of the regions correctly.

All these regions have a low population density, but there are economic differences in terms of GDP per capita between the regions of Northern, Southern, and Eastern Europe. It is worth noting that the energy sector was a key sector (before the arrival of renewable energies) in the Centro (PT16) and Sud-Est (RO22) regions. According to the input-output indicators, the energy sector was a strategic sector for the region of Galicia while irrelevant for the German regions.

Finally, to analyse the possible intra-regional variation of the potential impacts observed at NUTS 2 level, the impacts on the NUTS 3 regions that make up the five NUTS 2 regions presented above are calculated. Therefore, the analysis extends from five NUTS 2 treated regions to 44 NUTS 3 treated regions[11], and the control group extends from 77 NUTS 2 regions to 249 NUTS 3 regions (see Table SI.8 in SI with the NUTS 3 regions forming the control group). The variables used are the same as those presented above from the ARDECO database (see Table SI.9 in SI with the previous characteristics of the NUTS 3 regions treated).

4 | Results

4.1 | Case of Centro Portugal Region (PT16)

As can be seen in Figure 2, the expansion of renewables in the Portuguese Centro region starts at the beginning of the 21st century and reaches the maximum annual installed capacity in 2008. From this moment on, the trajectory stagnates. Therefore, the year used as the intervention year for the calculation of the counterfactual for the Portuguese Centro region is 2003, year prior in which the installation of renewable energies began in the region. The development of renewables in this region is mainly wind energy, which is the largest source of installed power in the region (100% of installed capacity in the year 2003).

The results provided by the SCM are shown in Figure 3. As can be seen, the evolution of the magnitudes at the time before the intervention is like the study region and its counterfactual, corroborating that the model is working correctly (also

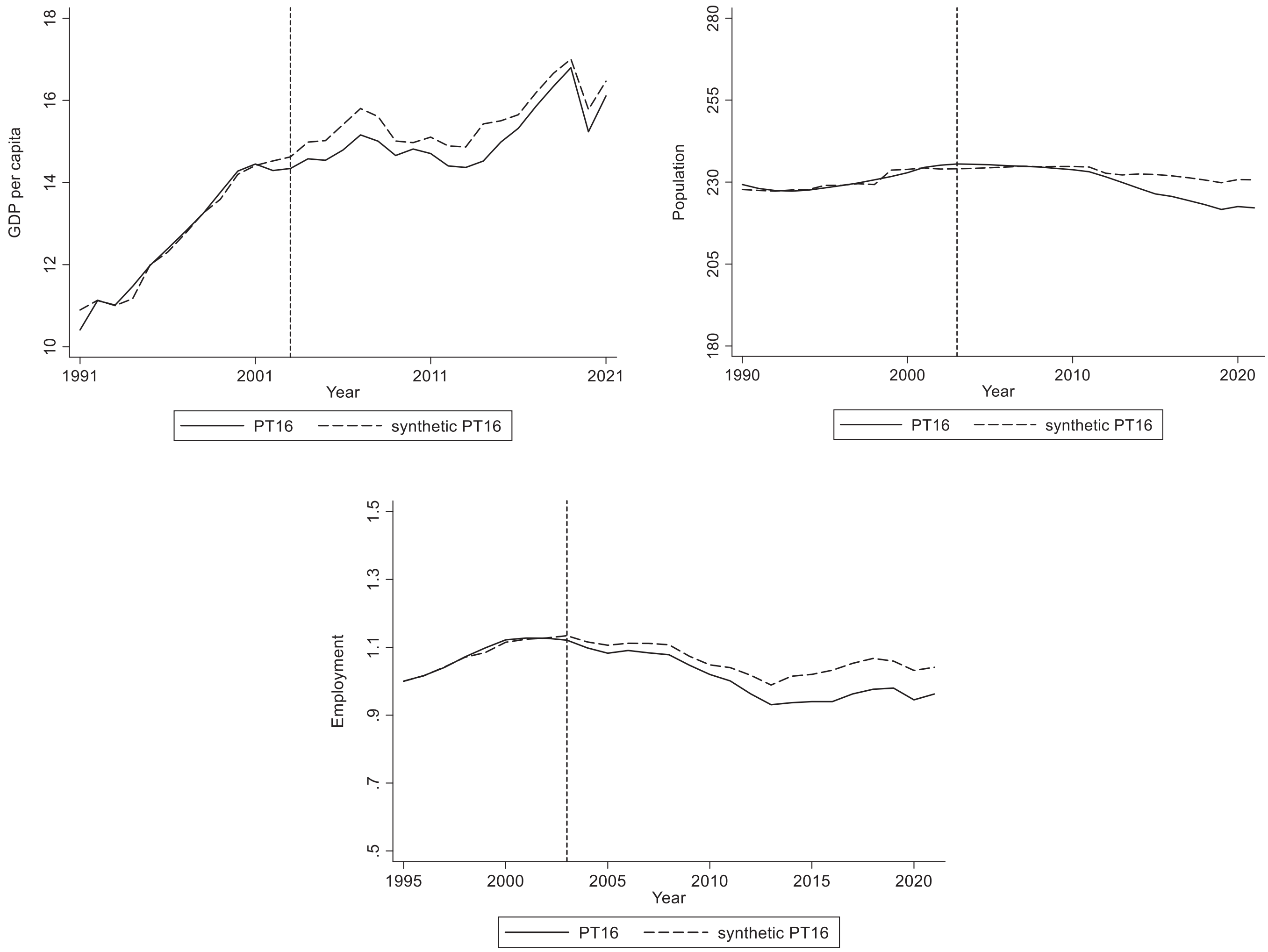

FIGURE 3 | Evolution of the variables under study in Centro region (PT16) and their synthetic indicator.

corroborated by placebos in space, Figure SI6 in SI). Furthermore, the impact observed between the actual trajectory of the region under study and the estimated trajectory (counterfactual) from the time of intervention is analysed. If the results in the post treatment trajectory are higher than the trajectory of the counterfactual, this means a positive impact and vice versa.

As can be seen, for this region, the development of renewable energies does not imply a significant impact on GDP per capita; the trajectories are similar for both the selected region and the counterfactual (see Figure 3). Moreover, it can be observed that impact on the population (top-right side) is negative at the end of the period, with an estimated population lose, on average, of 74,000 inhabitants between 2014 and 2021, period in which the gap becomes relevant and increases. However, if we analyse this result in the long term in comparison with the initial population, this is a nonsignificant impact on the population. There is only a 1.4% decrease from the initial population size as is corroborated by placebos in space (Figure SI.3 in SI) and *p*-values (Table 6). Finally, the impact on employment is negative and significant in the long term, with a loss of around 10% of employment regarding the figures achieved in 2020 (see Figure 3 bottom side).

Therefore, analysing "in-space placebos" (Figure SI.3 in SI) and *p*-values (first row of Table 6), we can deduce that there is no significant impact of renewable energies on per capita income (GDP per capita) nor on the population size. However, a significant negative impact on employment is observed. Moreover, the results are robust to the composition of the vector of weights W, since the results do not vary depending on the regions that are part of the counterfactual (see Figure SI.8 in SI).

Finally, the impacts at NUTS 3 level are analysed (Table 1). Although there is no effect on GDP per capita at NUTS 2 level, a significant negative effect is found for the Região de Aveiro, which could have a GDP per capita 4.5% higher than at present. The same is true for population, where negative results are found for the regions of Região of Coimbra, Viseu Dão-Lafões, and Beiras e Serra da Estrela. These last two regions stand out for being poor and low dense regions, with low sectoral weight of the industrial sector. Finally, the negative impact observed at NUTS 2 level is also observed at NUTS 3 level, except in Região de Aveiro, Viseu Dão-Lafões, and Beira Baixa, showing consistency in the results.

4.2 | Case of Galicia Spain Region (ESs11)

The expansion of renewables in the Spanish region of Galicia began at the end of the 20th century, and in 2007 it reached its

TABLE 1 | Average treatment effect on treated (ATT). NUTS3-Centro (PT16).

NUTS3	NAME	GDP per capita	Population	Employment
PT16B	Oeste	−1.612	14.867	−0.216***
		(0.357)	(0.325)	(0.004)
PT16D	Região de Aveiro	−3.304*	3.005	−0.122
		(0.088)	(0.905)	(0.105)
PT16E	Região de Coimbra	−1.323	−28.554**	−0.158**
		(0.273)	(0.024)	(0.039)
PT16F	Região de Leiria	−2.033	−1.092	−0.261***
		(0.177)	(0.940)	(0.008)
PT16G	Viseu Dão-Lafões	0.071	−19.108*	−0.144
		(0.944)	(0.052)	(0.191)
PT16H	Beira Baixa	0.209	−0.641	−0.052
		(0.831)	(0.921)	(0.327)
PT16I	Médio Tejo	−2.091	−10.393	−0.256**
		(0.221)	(0.190)	(0.035)
PT16J	Beiras e Serra da Estrela	0.249	−26.356*	−0.184*
		(0.795)	(0.091)	(0.082)

Note: ATT is calculated as: $\sum_{t0}^{T^0}(Y_{treated} - Y_{synthetic}) - \sum_{T^0}^{T}(Y_{treated} - Y_{synthetic})$. p-values in (), calculated according to Equation (9).
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

peak with 550 MW of installed capacity that year. From 2007 onwards, the annual installed capacity went into decline. In recent years, a firm commitment to using renewable energies has come back (see Figure 2). Therefore, 2000 was determined to be the intervention year. The renewable energy expansion has been based on wind energy (100% of installed capacity in the year 2000).

Figure 4 displays the impacts of the deployment of renewables in this region. A limited positive impact on GDP per capita is observed since 2006, but it is not statistically significant (see in-space placebos in Figure SI.4 in SI and p-values in Table 6). However, there is a clear positive and significant impact on the population; the trajectory of the population has remained constant over time in Galicia, while that of the synthetic control has been decreasing since 2002. Finally, a positive and significant impact on employment is observed (see p-value in Table 6). On average, our results suggest that the current employment is 14% higher than it would have been without the installation of renewable energy.

Therefore, these results suggest that although the development of this type of infrastructure has not been a relevant source of regional wealth, it has been capable of generating employment and retaining the depopulation effect observed in the synthetic Galicia. However, the results suggest that the arrival of renewable energies has not had an expulsive effect on the population at the regional level and in turn has been able to retain employment. Furthermore, the "leave-one-out" test (Figure SI.9 in SI) shows that the results are robust to the choice of regions in the counterfactual.

The results at NUTS 3 level for Galicia are consistent with the impact at NUTS 2 level (Table 2). No positive effect of renewable energies on GDP per capita is found at any regional level. At a more disaggregated level, the positive impact found at NUTS 3 level is concentrated in the regions of A Coruña and Pontevedra, which are the most populated, densely populated, and wealthy regions. Obviously, a series of demographic changes is also taking place within the region with a strong intra-regional migration between peripheral and coastal areas (see Martínez-Filgueira et al. 2017). The positive employment impact is concentrated in Pontevedra, the most densely populated region. Briefly, the positive impacts are not evenly distributed intra-regionally, with the most dense and economically dynamic NUTS 3 regions absorbing them.

4.3 | Case of Sachsen-Anhalt Germany Region (DEE0)

This region presents a distinct pattern; installation started at the end of the 20th century and there is an almost constant annual capacity installation during the rest of the period. For this reason, the year 2000 is chosen as the intervention year. Therefore, this region allows us to examine the impact of renewable energies in a region where installation has occurred continuously (see Figure 2). The most power installed capacity was in 2009. The development of renewables in this German region has been strongly based on wind energy (99% of installed capacity in the year 2000).

It can be seen in Figure 5 that the impact on GDP per capita has been positive in the long term but not significant (see Figure SI.5 in SI and p-value in Table 6). However, the installation of renewable energy has not managed to reverse or halt the downward trend in population size. Significant results suggest that the population loss would have been smaller

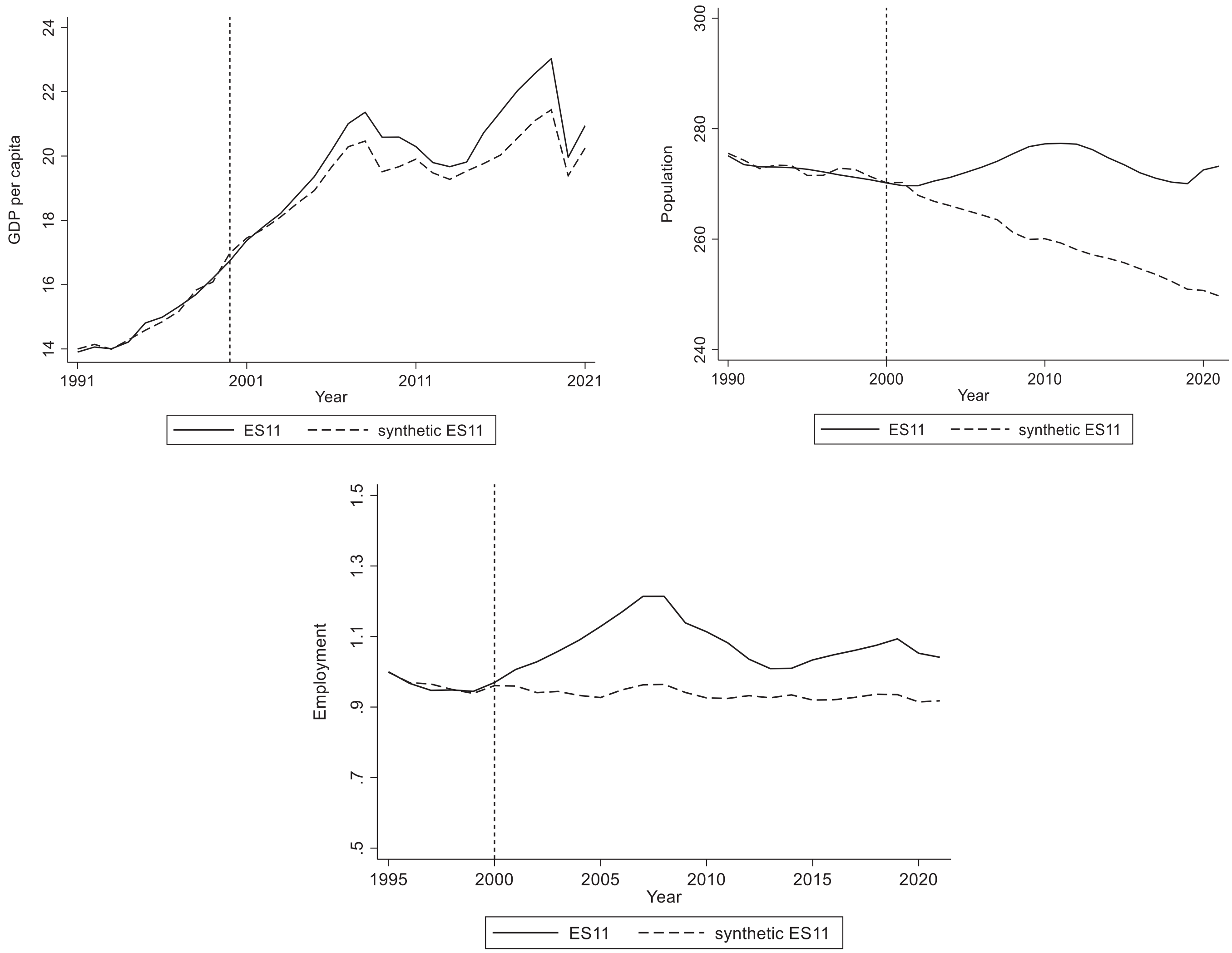

FIGURE 4 | Evolution of the variables under study in Galicia region and their synthetic indicator. Galicia (ES11).

TABLE 2 | Average treatment effect on treated (ATT). NUTS3-Galicia (ES11).

NUTS3	NAME	GDP per capita	Population	Employment
ES111	A Coruña	0.842	37.423*	0.154
		(0.687)	(0.091)	(0.648)
ES112	Lugo	1.342	−14.396	0.108
		(0.406)	(0.531)	(0.316)
ES113	Ourense	2.059	−16.046	0.047
		(0.301)	(0.329)	(0.119)
ES114	Pontevedra	0.757	52.580*	0.011**
		(0.691)	(0.095)	(0.047)

Note: ATT is calculated as: $\sum_{t0}^{T^0}(Y_{treated} - Y_{synthetic}) - \sum_{T^0}^{T}(Y_{treated} - Y_{synthetic})$. p-values in (), calculated according to Equation (9).
$^*p < 0.1$; $^{**}p < 0.05$.

without the installation of renewables. Moreover, renewable energy installation had a negative and significant impact on employment. It is estimated that employment would have fallen by around 13% compared to the situation before the installation of renewables, with these results being robust to donor pool checks (see Figures SI.5 and SI.10 in SI and Table 6).

Consequently, the results suggest that the massive installation of renewable energies in this region has not only failed to generate wealth but has also accentuated the process of depopulation and employment de-localization.

Again, the results at NUTS 3 level are consistent with those found at NUTS 2 level in this region (see Table 3). First, no

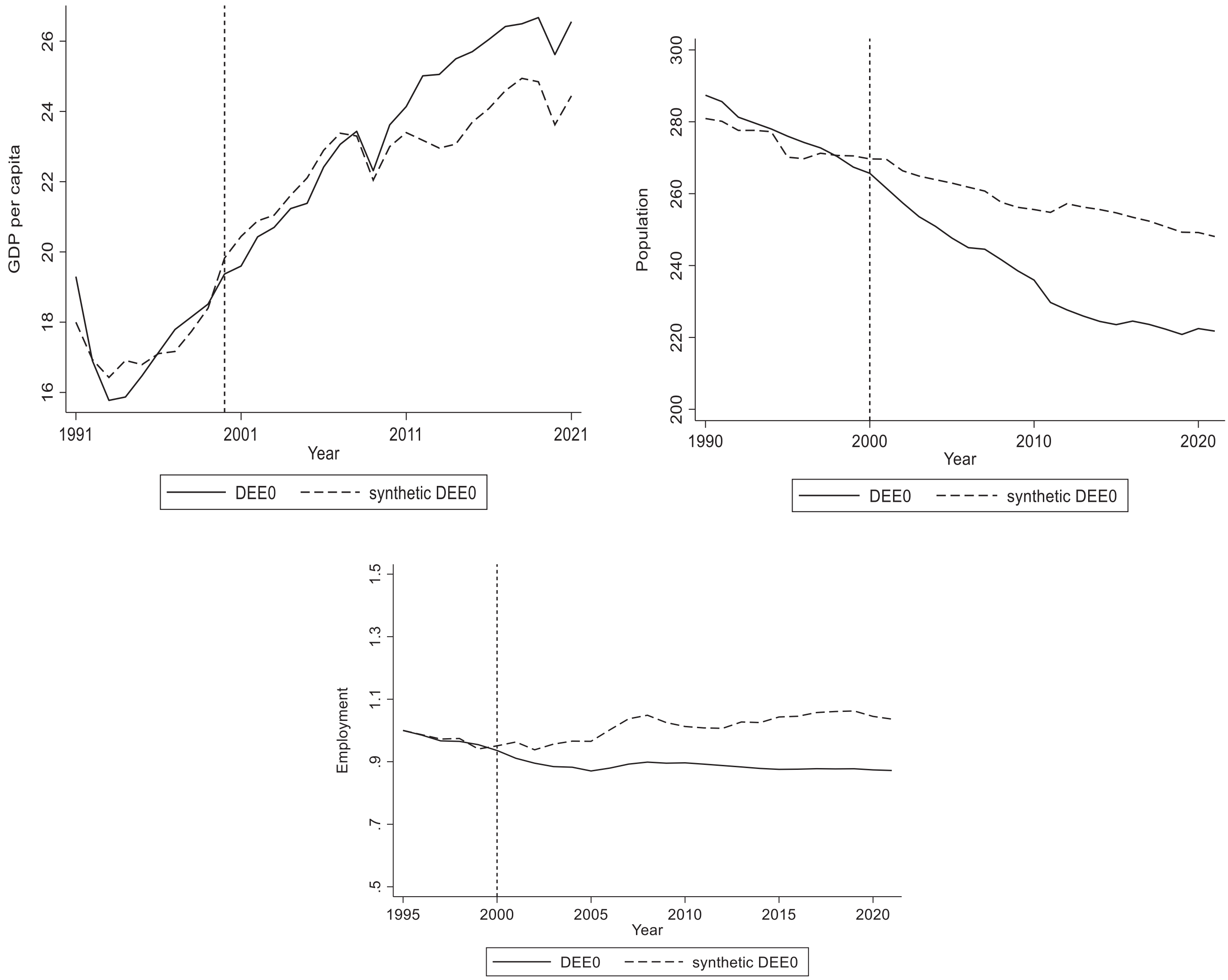

FIGURE 5 | Evolution of the variables under study in Sachsen-Anhalt region and their synthetic indicator. Sachsen-Anhalt (DEE0).

significant impact on GDP per capita is found at any scale. Moreover, a significant negative impact on population is concentrated in Anhalt-Bitterfeld, Harz and Salzlandkreis. The areas that lose more population than they should are intermediate areas in terms of population, they are not the most densely populated, but neither are they the least densely populated within the region. Employment loss is concentrated in Burgenlandkreis and Mansfeld-Südharz, among the poorest within the region.

4.4 | Case of Niederbayern Germany Region (De22)

The expansion of renewable energies in the German region of Niederbayern (see Figure 2) began at the beginning of the 21st century and reached its peak in 2010 (around 1000 MW of installed capacity between 2009 and 2010). After that year, the installation process stagnated until 2018 and increased again. Therefore, 2005 is chosen as the intervention year, as the installation of renewable energies started strongly in the following years.

Specifically, the development of renewables in this region is based on the development of photovoltaic energy (99.6% of the renewable energy mix installed in 2005). This is the only region under study committed to using photovoltaic energy. Furthermore, it is recognised in the literature (Kahla et al. 2017; Punt et al. 2022) that this region is the German region that had the highest installation of renewable energy co-operatives. At the same time, the average size of photovoltaic installations in, what shows the type of management model for the expansion of renewables in this region based on small photovoltaic installations, probably encouraging self-consumption and, as has just been noted in the literature, energy cooperatives.

A positive and significant impact on GDP per capita is observed in this region (see Figure 6). In the long run, the effect of the population has been null as the regional trajectory and that of the counterfactual overlap. However, in the short term, there was a negative effect, although this was transitory. For this region, renewable energies have positive and significant effects on employment (see Table 6), with employment rates above 10%. Results are also robust to the counterfactual regions (see Figure SI.11 in SI).

We could see this region as a story of success, in the terms evaluated, as the development of renewable energy has had a

TABLE 3 | Average treatment effect on treated (ATT). NUTS3- Sachsen-Anhalt (DEE0).

NUTS3	NAME	GDP per capita	Population	Employment
DEE01	Dessau-Roßlau, Kreisfreie Stadt	−1.346	−15.328	−0.164
		(0.639)	(0.279)	(0.183)
DEE02	Halle (Saale), Kreisfreie Stadt	−3.361	−52.234	−0.185
		(0.338)	(0.218)	(0.300)
DEE03	Magdeburg, Kreisfreie Stadt	−2.250	−28.113	−0.104
		(0.456)	(0.435)	(0.510)
DEE04	Altmarkkreis Salzwedel	0.258	−12.533	−0.118
		(0.913)	(0.271)	(0.350)
DEE05	Anhalt-Bitterfeld	−0.867	−46.713*	−0.111
		(0.814)	(0.080)	(0.532)
DEE06	Jerichower Land	−2.979	−9.018	−0.151
		(0.183)	(0.370)	(0.198)
DEE07	Börde	1.653	−21.501	−0.126
		(0.437)	(0.160)	(0.163)
DEE08	Burgenlandkreis	−0.609	−42.635	−0.153*
		(0.779)	(0.115)	(0.084)
DEE09	Harz	−3.502	−41.188*	−0.121
		(0.144)	(0.092)	(0.144)
DEE0A	Mansfeld-Südharz	−3.107	−37.439	−0.211*
		(0.160)	(0.126)	(0.099)
DEE0B	Saalekreis	2.155	−25.311	−0.089
		(0.506)	(0.149)	(0.403)
DEE0C	Salzlandkreis	1.140	−48.211*	−0.064
		(0.559)	(0.076)	(0.483)
DEE0D	Stendal	−1.409	−25.420	−0.150
		(0.605)	(0.183)	(0.357)
DEE0E	Wittenberg	0.233	−30.800	−0.160
		(0.920)	(0.156)	(0.167)

Note: ATT is calculated as: $\sum_{t0}^{T^0}(Y_{treated} - Y_{synthetic}) - \sum_{T^0}^{T}(Y_{treated} - Y_{synthetic})$. *p*-values in (), calculated according to Equation (9).
$^*p < 0.1$.

positive impact on economic growth and employment without affecting population. This result is not surprising, as the literature finds that wind energy does not generate local employment (Costa and Veiga 2021; Fabra et al. 2022). However, photovoltaic energy, and in particular those installation models that could be more respectful of the territory can generate positive effects on employment.

In Niederbayern, the results at NUTS 3 level continue to show consistency with the regional NUTS 2 level and intra-regional variation (Table 4). The positive impact on GDP per capita has been concentrated in 4 sub-regions (Landshut, Landkreis, Rottal-Inn, Straubing-Bogen and Dingolfing-Landau), which are the least economically developed, except for Dingolfing-Landau, less dense, agricultural sector is predominant, but have the highest investment (in terms of GDP) of the whole region. In short, this region offer positive insights at all the spatial levels, because it has managed to increase its GDP per capita with the arrival of renewable energies at NUTS 2 level (the only region to do so) and this impact is also being felt in the most backward regions, giving rise to a process of intra-regional convergence. In terms of population, no significant effect is found at any geographical level. However, the positive impact on employment is concentrated in Landshut, Kreisfreie Stadt, Passau, Kreisfreie Stadt and Straubing, Kreisfreie Stadt, which are the NUTS 3 regions with the highest GDP per capita and population density within Niederbayern.

4.5 | Case of Sud-Est Romania Region (RO22)

The use of renewables in the Romanian region Sud-Est started in 2006 (Figure 2). It reached its peak in 2009 with an annual installed capacity of 1500 MW between 2008 and 2009. This is the case of the most explosive trend as it went from having no installed capacity to having around 3000 MW in only 3-4 time

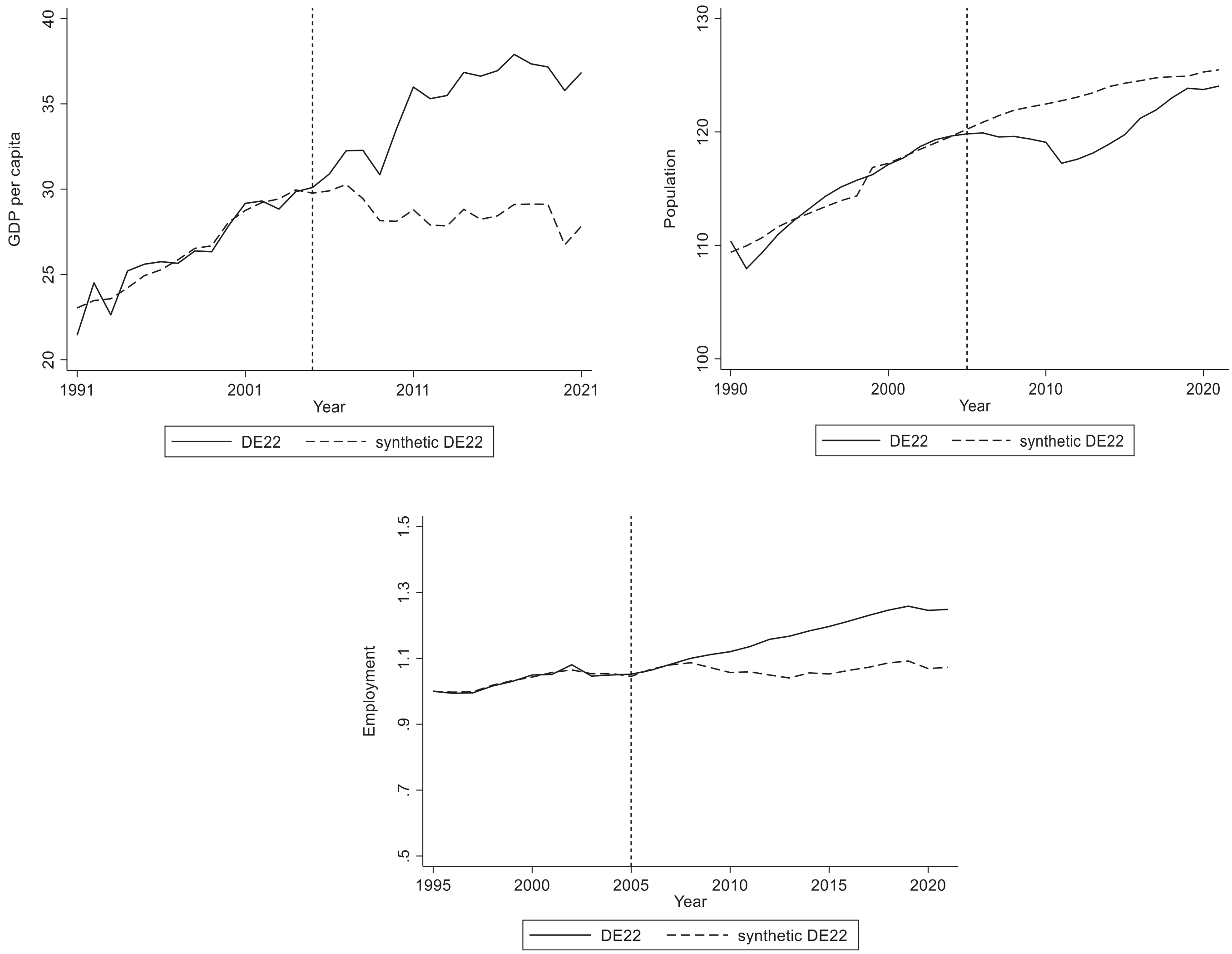

FIGURE 6 | Evolution of the variables under study in Niederbayern region and their synthetic indicator. Niederbayern (DE22).

periods. Therefore, impacts from 2005 onwards are analysed as the year of intervention. The development of renewable energies in this region is based on wind energy (100% of installed capacity in the year 2005).

Impacts on both GDP per capita and population are negative, albeit small (Figure 7). Although, they are significant only for the case of the population in line with placebos in space (Figure SI.7 in SI and Table 6). No impact of renewable energies on employment is observed in this region.

Finally, no impact on GDP per capita is observed at NUTS 3 level either. In this case, the negative impact on the population is concentrated in the Buzau region, which is one of the regions with the lowest GDP per capita and investment per GDP in the Romanian region. However, although we do not find impacts on employment at NUTS 2 level, we do find heterogeneity of impacts at NUTS 3 level, where the Galati region has gained employment, and the rest have lost it (Table 5). This region stands out as one of the richest and most densely populated.

Table 6 displays the *p*-values for the analysis of the significance of the estimated effect. These results are complemented by the remaining inference analysis discussed in this section. Placebos in space show that the existence of potential confounders is limited, as no significant effects are observed in regions not subject to the intervention.

Finally, the results estimated with the Synthetic Difference in Difference are summarised in Table 7. We found that all the effects estimated under this novel model have the same sign and significance as the results presented above, giving validity to our previous results. The only difference is found in the case of employment in the Sachsen-Anhalt region, where a negative impact is observed, but in this case, it is not significant.

5 | Discussion

The analysis presented above show some common features and also significant differences regarding the long-term economic and social effects of the deployment of renewable energies in the European rural regions analysed as case studies.

First, regarding the effects on income, our findings suggest that the development of renewable infrastructures in rural areas in Europe can be a source of income growth, as shown with the positive impact on income found for the Niederbayern region.

TABLE 4 | Average treatment effect on treated (ATT). NUTS3-Niederbayern (DE22).

NUTS3	NAME	GDP per capita	Population	Employment
DE221	Landshut, Kreisfreie Stadt	−0.623	4.873	0.169***
		(0.893)	(0.248)	(0.004)
DE222	Passau, Kreisfreie Stadt	7.095	−2.672	0.114**
		(0.170)	(0.668)	(0.031)
DE223	Straubing, Kreisfreie Stadt	1.595	−0.755	0.174***
		(0.536)	(0.880)	(0.008)
DE224	Deggendorf	0.028	−2.034	0.062
		(0.992)	(0.844)	(0.263)
DE225	Freyung-Grafeu	2.239	−1.237	−0.013
		(0.360)	(0.852)	(0.680)
DE226	Kelheim	2.219	6.886	0.011
		(0.296)	(0.636)	(0.892)
DE227	Landshut, Landkreis	6.437**	15.555	0.146
		(0.047)	(0.352)	(0.154)
DE228	Passau, Landkreis	1.477	−2.168	0.086
		(0.486)	(0.836)	(0.174)
DE229	Regen	3.323	−4.301	0.013
		(0.111)	(0.572)	(0.691)
DE22A	Rottal-Inn	4.230**	−0.650	0.040
		(0.084)	(0.924)	(0.390)
DE22B	Straubing-Bogen	3.997**	7.357	0.108
		(0.028)	(0.435)	(0.197)
DE22C	Dingolfing-Landau	9.155**	0.592	0.148*
		(0.024)	(0.728)	(0.099)

Note: ATT is calculated as: $\sum_{t0}^{T^0}(Y_{treated} - Y_{synthetic}) - \sum_{T^0}^{T}(Y_{treated} - Y_{synthetic})$. *p*-values in (), calculated according to Equation (9).
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Regarding the characteristics of this region before the intervention (Table SI2), we can see that this German region is more developed and with a productive structure based on a higher representation of industrial and financial sectors, as well as a higher level of tertiary education. Moreover, this region had lower values of backward and forward linkages for the energy sector, which could reflect a low integration of the traditional energy sector in the global that facilitates the development of renewable energies.

This is the only region for which a positive impact on GDP per capita is found. In all other regions, there is no impact on wealth. This may be due to the reasons mentioned in the previous paragraph, since to transform investments in renewable energies into regional wealth, the region must have an economic system capable of channelling these investments. Therefore, it seems clear that a certain degree of economic development, a specialised productive structure in the sectors mentioned above, and a qualified population are necessary to be able of channelling these investments. The rest of the regions, with a less integrated economic structure and more limited backward and forward linkages for the energy sector, are likely to see this potential positive impact diminished. Intra-regional analysis of the potential impact on GDP per capita shows that the only NUTS 3 regions with a positive impact on GDP per capita are found in the Niedebayern region (NUTS 2), making the results consistent. This positive intra-regional impact is concentrated in the poorest and most agricultural regions. However, despite being the poorest at the intra-regional level, they remain among the richest NUTS3 regions at the inter-regional level (see Table SI.9 in SI), showing the importance of the previous economic structure, as we have argued. In essence, our results suggest that having a positive impact on wealth generation from renewable energies requires a certain prior structure able to channel it. The nonsignificant impact on the richest regions within the region can be explained by the marginal effect that renewable energies may have on regional GDP. Moreover, these NUTS 3 regions with positive effects on GDP per capita are those that are located close to other regions in Southern Germany[12]. Spatial location and spillover effects may be important in explaining the impact of renewable energies in GDP per capita at territorial level.

Regarding the impact on the population, our findings indicate that in regions experiencing population declines (Sachsen-Anhalt and Sud-Est), the adoption of renewable energies may

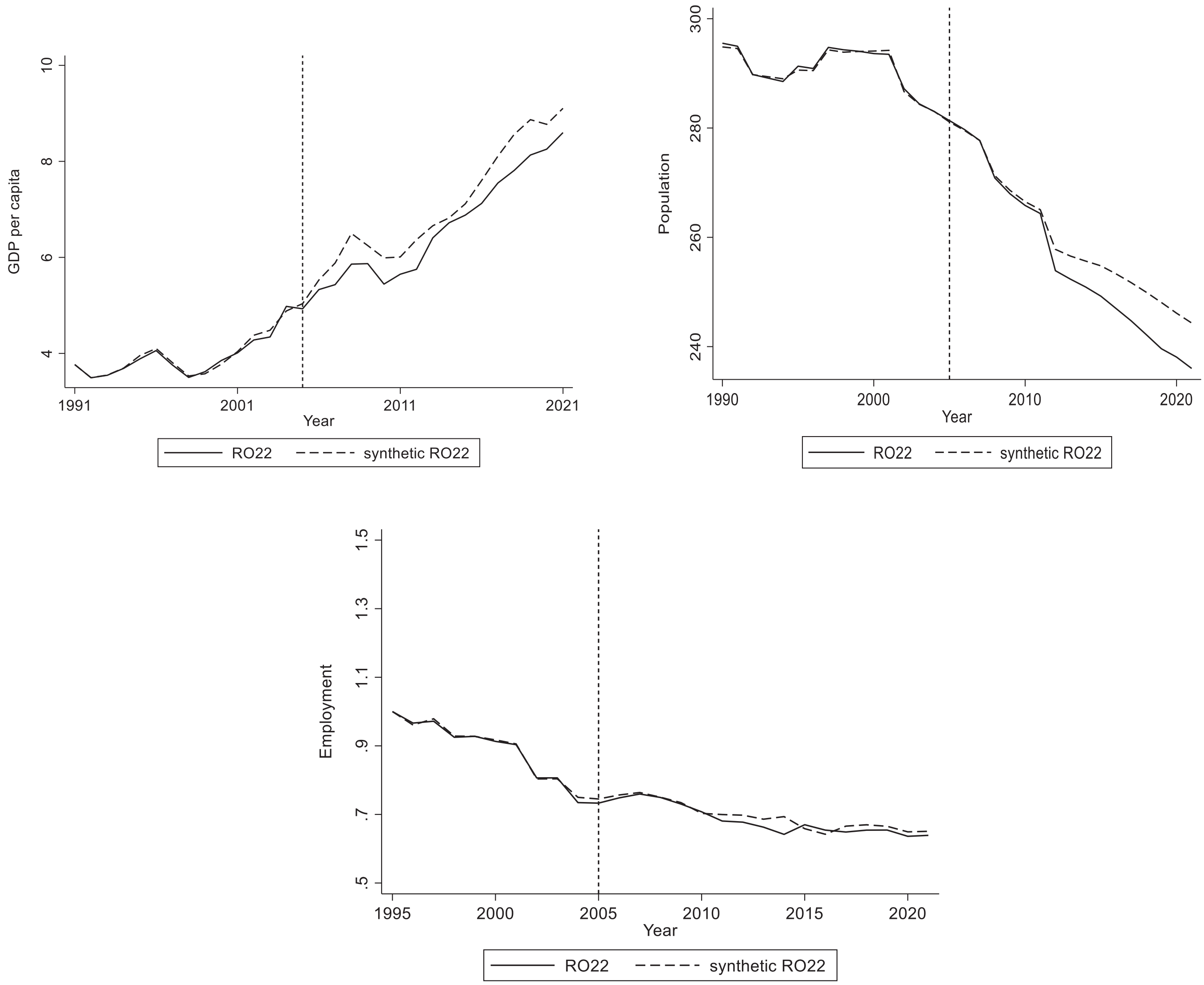

FIGURE 7 | Evolution of the variables under study in Sud-Est region and their synthetic indicator. Sud-Est (RO22).

TABLE 5 | Average treatment effect on treated (ATT). NUTS3-Sud-Est (RO22).

NUTS3	NAME	GDP per capita	Population	Employment
RO221	Braila	0.605	−15.304	−0.012**
		(0.609)	(0.199)	(0.075)
RO222	Buzau	−0.204	−12.897***	−0.065***
		(0.871)	(0.008)	(0.004)
RO223	Constanta	1.589	21.934	−0.120***
		(0.343)	(0.134)	(0.000)
RO224	Galati	−0.525	−20.139	0.081**
		(0.730)	(0.203)	(0.012)
RO225	Tulcea	1.111	−10.653	−0.013**
		(0.415)	(0.297)	(0.032)
RO226	Vrancea	0.253	−14.955	−0.072***
		(0.839)	(0.280)	(0.008)

Note: ATT is calculated as: $\sum_{t_0}^{T^0}(Y_{treated} - Y_{synthetic}) - \sum_{T^0}^{T}(Y_{treated} - Y_{synthetic})$. *p*-values in (), calculated according to Equation (9).
$^{**}p < 0.05$; $^{***}p < 0.01$.

TABLE 6 | *p*-values of the estimated effects.

	GDP per capita		Population		Employment	
	***p*-value**[a]	***p*-value**[b]	***p*-value**[a]	***p*-value**[b]	***p*-value**[a]	***p*-value**[b]
Centro (PT16)	0.6617	0.6764	0.1866	0.5466	0.10*	0.1923
Galicia (ES11)	0.32	0.2166	0.001***	0.1866	0.0270**	0.0945
Sachsen-Anhalt (DEE0)	0.32	0.5066	0.001***	0.0129	0.0533*	0.1282
Niederbayern (DE22)	0.0131**	0.0657*	0.2368	0.5394	0.0447**	0.0149**
Sud-Est (RO22)	0.6041	0.2291	0.096*	0.1506	0.8507	0.5671

[a]: is calculated only by taking into account the RMSPE post-intervention in the Equation (9).
[b]: is calculated according to Equation (9).
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

TABLE 7 | Average treatment effect on the treated (ATT).

	PT16	ES11	DEE0	DE22	RO22
GDP per capita	−0.02	0.66	1.17	3.86**	0.15
	(1.57)	(1.50)	(1.78)	(2.04)	(1.92)
Population	−5.54	08.58*	−8.78**	−2.36	−8.17**
	(9.22)	(4.60)	(3.75)	(3.03)	(3.65)
Employment	−0.009*	0.14**	−0.06	0.08**	−0.02
	(0.004)	(0.09)	(0.06)	(0.06)	(0.07)

Note: Standard errors in parentheses.
*$p < 0.1$; **$p < 0.05$.

not only fail to curb depopulation but could intensify it. Therefore, the notion of using renewable energy deployment in rural areas as a solution to combat depopulation should be approached with caution. Moreover, if we look at the intra-regional impacts on employment, we find that these significant negative impacts are concentrated in the NUTS 3 regions with lower GDP per capita and population density (NUTS 3 cases in PT16 and RO22) and in the intermediate NUTS 3 regions of Sachsen-Anhalt. However, the positive impact observed in Galicia is concentrated in the richer and more densely populated NUTS 3 sub-regions. In short, the installation of renewable energies seems to perpetuate and accelerate in several regions the pattern of population agglomeration in urban areas and depopulation in less densely populated areas.

The impact on population is closely linked to the effects on employment variables, as employment dynamics primarily drive both inter- and intra-regional migrations over the long term. It becomes evident that regions experiencing either a negative impact (Sachsen-Anhalt) or no impact (Sud-Est) on employment also witness negative effects on their population. As previously mentioned, a negative impact on employment and on the population in the long term is also observed in the Centro region, although in this case, not statistically significant. Conversely, regions like Galicia exhibit positive employment impacts, which subsequently influence population trends. Additionally, the Niederbayern region, while not showing a positive impact on population, stands out as the only region constantly increasing its employment. These results are in line with the literature (see Costa and Veiga 2021 and Fabra et al. 2022), where it is acknowledged the limited and transitory capacity of the renewable energy sector to generate direct local employment, given its capital-intensive and not labour-intensive character. Regarding its indirect effects, these can be both positive and negative. On the one hand, the energy sector can generate positive effects by generating an ancillary industry to this sector, or by enabling the industry present in the region to grow by reducing energy costs. On the other hand, a crowding out effect on local employment can be generated, as it could deteriorate the agricultural sector, via increased land prices (Geoghegan and O'Donoghue 2023) or the tourism sector (see Tverijonaite et al. 2022) as the region becomes less attractive. These indirect effects have been more difficult to quantify in the literature (Lambert and Silva 2012).

For our particular case, as we have just checked, we find positive (Galicia and Niederbayern), negative (Sachsen-Anhalt and Centro), and null (Sud-Est) total local effects. At NUTS 3 level, we find that both in the case of Galicia and in the case of Niederbayern, the positive impacts on employment have been concentrated in the richer and more densely populated NUTS 3 regions. However, the negative impact of region Sachsen-Anhalt is concentrated in the poorer regions, while for region Centro it is evenly distributed over almost all NUTS 3 regions. Finally, although there is no impact on employment at NUTS 2 level, there is an impact at NUTS 3 level in the Sud-Est regions, with the positive impact concentrated in the richest and most densely populated region. In short, the potential impact generated by the installation of renewable energies seems to be concentrated in the areas with the highest GDP per capita and population density.

In summary, our results suggest that energy objectives can be achieved together with economic and social (employment) objectives (case of Niederbayern). However, also in line with the literature and other experiences, these cannot be taken for granted (this has not been the case in Sachsen-Anhalt, Centro and Sud-Est regions).

At the same time, as already mentioned above, the regional energy policy management model for renewable energies is also important. These potential benefits of the energy transition should not be taken for granted, and must be adapted to the characteristics of each region. At the same time, there is no doubt that the management model of territorial integration matters for the results, since, as we have just seen, the success story of Niederbayern is contextualized on an energy model based on photovoltaic energy, small installations and energy cooperatives.

6 | Conclusions and Future Research

This paper analyses the impact of renewable energies in European rural areas. Particularly we aim to analyse to what extent the development of renewable energies has channelled into long-term positive socioeconomic impacts in the European rural territory where the wind and photovoltaic farms are often installed. Specifically, the impacts of renewable energy installation on GDP per capita, population, and employment are analysed through case studies of European rural regions. Case studies are a relevant tool for analysing the issues raised in this paper. However, the policy implications and conclusions derived from this study should avoid generalisations, as the heterogeneity in results observed may vary depending on the territories and the scale of analysis used. Nevertheless, this first approximation for these case studies is useful as an initial guide on how to achieve potential positive impacts on the territory linked to the installation of renewable energies.

To this end, our analysis focuses on case studies in those rural NUTS 2 regions with the highest installed capacity of renewables and a long track record of installation over time, and then extends to their respective NUTS 3 regions. This paper discusses to what extent the development of renewable infrastructures on rural areas in Europe has been a significant source of economic growth, employment generation, and also a factor to reverse the rural depopulation trends. In sum, it is studied the potential compatibility between socioeconomic and a sustainable development based on renewable energy, in the context of a spatially just energy transition.

The novelty of this study is two-fold. First, a novel database on installed power in renewable energies at the NUTS 2 level of disaggregation is developed. Second, the use of the synthetic control method and other novel extensions, such as synthetic difference in differences as a robustness check, to estimate the impacts of these energy sources on the rural territory based on the study on three variables: GDP per capita, population and employment.

Our findings show that the case of success is found in the German region of Niederbayern, with positive long-term results in terms of GDP per capita and employment.

In our view, two main factors account for this phenomenon, as elaborated in the preceding section: the economic structure of the region and the regional energy policy model. Concerning the latter, we can highlight three pivotal aspects observed: the widespread utilization of photovoltaic energy, a significant presence of renewable energy cooperatives, and the prevalence of smaller-scale photovoltaic projects.

Thus, one of the first reflections we can draw from these results is that the exploitation model of natural resources matters for the economic and social performance of the rural territories involved. In the German region of Niederbayern, the installed capacity of renewables is similar to the rest of the regions analysed, but both the exploitation model and the results obtained are different from the rest of the regions. In summary, the model of implementation and exploitation of renewable energies (size of installation, technology and form of management) seems to lead to positive socioeconomic results at regional level, for our case study. In the case of Niederbayern, a bottom-up regional and energy policy approach, where local management is important, achieves sustainable socioeconomic development. This approach minimises possible negative effects on other sectors, since it takes into account the territory and the people involved (Međugorac and Schuitema 2023). In this case, it is corroborated that this type of regional energy policy increases the probability of positive outcomes linked to the installation of renewable energy infrastructures.

On the contrary, more limited or even negative effects are found in the Portuguese region Centro, in the German region Sachsen-Anhalt and in the Romanian region Sud-Est, where the impact on GDP per capita is non-existent or negative, in each case; and the effects on population are negative in both cases. In the case of Galicia, a positive impact on the population and employment is found, despite not generating wealth in the territory, has been able to maintain the existing population, slowing down the process of depopulation and create new job opportunities.

Extending the impact analysis to the NUTS 3 regions of these five NUTS 2 regions, we find that there is also an intra-regional heterogeneity of the potential impacts linked to the installation of renewable energies. This multi-scale analysis allows a more comprehensive analysis of these potential impacts. The potential impacts are not homogeneously distributed within the territory. Nevertheless, they are consistent at both regional scales.

This intra-regional variation shows that the positive impacts on population and employment are concentrated in the richer and more densely populated sub-regions, while the negative impacts are concentrated in the poorer and more sparsely populated sub-regions, demonstrating the importance of agglomeration factors in the development and installation of renewable energies. In terms of impacts on GDP per capita, it seems that renewable energies can increase the GDP per capita of those regions with a certain level of GDP per capita, i.e., it is necessary to have good economic conditions. Regions with poorer economic conditions, at all levels (NUTS 2 or NUTS 3) are unable to translate the installation of renewable energy into wealth. There seems to be an inverted U relationship between GDP per capita and the potential impact on it. However, we should pay more attention to this in the future.

Therefore, this important regional heterogeneity in terms of the long term results of the development of renewable energy infrastructures in the rural Europe from the perspective of its capacity to mobilize income and local employment, contributing to population fixation, suggests the need of a coordinated and coherent land-use policy to maximise the benefits associated with renewables and thus generate an economically and socially sustainable rural development. Of course, the opportunities that that development of this type of infrastructures, and the associated effects for the rest of the economy may generate, in addition to the environmental aspects has to be acknowledged, but this paper empathizes the need for policy actions and/or support mechanisms on where these benefits are generated. The renewable energy deployment process will generate important socioeconomic effects and changes in developed economies, but a policy approach involving the concept of a spatially just energy transition is so important. Rural areas have to be dynamized, but with a process adapted to the idiosyncrasy of these places is needed, to enhance their strengths. The rural regions analysed could become exporters of energy to urban areas, continuing the energy peripheralization of rural areas (O'Sullivan et al. 2020).

Therefore, the insights of this study highlight the relevance of the integration of place-based policies linked to the process of installing renewable energies, with measures and strategies to promote the development of these technologies together with the socioeconomic development of the territories. This highlight the need for politicians to avoid possible regional stagnation processes, since, as we have seen, the potential positive impact cannot be taken for granted in all the cases analysed. The European Union is already integrating this vision in its Cohesion Funds, horizon 2021-2027, doubling the financing for the installation of renewable energies with respect to the previous period (European Commission 2021). In short, this study remark the need for policy actions to achieve territorial cohesion through the installation of renewable energies. However, multi-scale mechanisms are necessary, since, as has been demonstrated in our case studies, intra-regional impacts are not evenly distributed. There is a risk that the more economically and densely populated sub-regions will be the beneficiaries of these funds, increasing intra-regional inequalities. Either concentrating funds in regions that are less likely to effectively channel these investments into positive outcomes—based on the characteristics analysed in this document—or preparing these regions through prior socioeconomic development before implementation, to ensure they can effectively channel these investments in positive outcomes, is essential for achieving socioeconomic and energy objectives.

This study serves as a basis for future research on the integration of renewable energies in the territories. These results are obtained at regional level, which involves intra-territorial economic and social differences. This highlights the need to deepen this type of analysis to be able to understand the effects at the smallest possible territorial disaggregation. The lack of data makes impossible to analyse energy balances at the European regional level, what opens up interesting future research. As mentioned above, these conclusions are derived from the analysis of case studies of specific European rural regions. The generalisation of these analyses in the future will allow for more concrete conclusions and policy implications that can help to integrate socio-economically sustainable renewable development. This analysis should incorporate other important aspects that may also influence the results, such as the intervention period, the speed, and the added capacity trajectory of the renewable energy installation process. The focus of the analysis has been on those regions considered as rural. However, the analysis of the process of renewable energy installation between urban and rural regions should be considered in the future, as well as possible asymmetries in the estimated impacts.

It is likely that spatial effects play an important role in the diffusion of the effects derived from the implementation of these technologies. The local installation, without effects, may be due to the fact that it is benefiting the nearest localities. Also, the location in space can influence the potential impacts of the installation of this technology. Therefore, future research could address spatial spillovers and spatial location effects.

In turn, in this study we have approximated the concept of sustainable development through three variables (GDP per capita, population and employment), but it is interesting to try to measure sustainable development through other welfare measures, as well as the impacts on the regional productive structure (what happens with the industries in the region). Not only that, as we have seen, the concept of spatial justice also implies the analysis of convergence and the importance of territorial cohesion. Therefore, it is important to analyse how energy policies and the development of renewable energies impact on the processes of convergence and regional inequalities in the socio-economically lagging regions.

Finally, reference has been made to the possible existence of a new natural resource curse, in this case related to the abundance of natural resources linked to the exploitation of renewable energy sources. Through our empirical approach, it has been observed that both the territorial benefits linked to the installation of renewable energies and this possible curse of natural resources cannot be guaranteed.

The idiosyncrasies, socioeconomic preconditions and energy management model of each territory determine the success or failure of the integration of these renewable technologies in the rural areas analysed.

To conclude, we are at a time when the fight against climate change, depopulation and rural development are priority objectives on the public and social agendas of European countries. Achieving this triple dividend should not be taken for granted, since, as seen in this study, meeting renewable energy objectives means failing to achieve the objectives of sustainable rural development. Hence, we advocate an energy and territorial management model that is compatible between social, environmental and economic objectives, to achieve an effective and sustainable spatially just energy transition.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Endnotes

[1] Refers to those places where coal is the fuel source for the subsequent thermoelectric generation of electricity (EMBER 2021).

[2] Recent literature assessed the territorial winners and losers of energy transition processes (Balta-Ozkan et al. 2015; Coutard and Rutherford 2010; Li et al. 2016; Mueller and Brooks 2020; Sayan 2019; Sovacool 2017).

[3] These costs have decreased significantly over the last ten years. By 2020 these multipliers would be 0.77 million euros per MW for photovoltaics and 1.18 million euros per MW for wind power (International Renewable Eneryg Agency, 2020).

[4] Note that we focus on wind and photovoltaic energy, as these are the predominant renewable energy sources at present while the process of expansion of other sources such as hydroelectricity has been historically different.

[5] The capacity approach proposed by Lehmann et al. 2024 is used to analyse local benefits and burdens in spatial justice work on renewable energy development.

[6] A sufficiently long time series of data is needed to perform this type of test. For our particular case study, as follows, this type of inference cannot be applied as it is not possible to go back far enough in time.

[7] All regions forming the control group can be seen in Table 2019; Sovacool SI.3 in the Supplementary Information.

[8] The analysis is extended with more variables, to avoid possible confounders. Specifically, the investment variable is disaggregated by sector: A: Agriculture, forestry and fishing; B-E: Mining and quarrying, manufacturing, electricity, gas, steam, air conditioning supply, water supply; sewerage, waste management and remediation activities and M-N: Professional, scientific and technical activities, administrative and support service activities (ARDECO, 2021). The results remain robust to the inclusion of these variables. These results are available upon request.

[9] The energy sector refers to mining, quarrying and energy supply, according to (Thissen et al. 2018) definition.

[10] The technical details of the calculation of these indicators can be found in Appendix C of the SI.

[11] Niederbayern contains 12 NUTS 3 regions; Sachsen-Anhalt 14 NUTS 3 regions; Galicia 4 NUTS 3 regions; Centr 8 NUTS 3 regions and Sud-Est 6 NUTS 3 regions.

[12] Niederbayern shares borders in the north (Oberpfalz) and west (Oberbayern) with other southern German regions, while in the south it shares borders with Austria and in the east with the Czech Republic.

References

Abadie, A. 2021. "Using Synthetic Controls: Feasibility, Data Requirements, and Methodological Aspects." *Journal of Economic Literature* 59, no. 2: 391–425. https://doi.org/10.1257/jel.20191450.

Abadie, A., A. Diamond, and J. Hainmueller. 2010. "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program." *Journal of the American Statistical Association* 105, no. 490: 493–505. https://doi.org/10.1198/jasa.2009.ap08746.

Abadie, A., A. Diamond, and J. Hainmueller. 2015. "Comparative Politics and the Synthetic Control Method." *American Journal of Political Science* 59, no. 2: 495–510. https://doi.org/10.1111/ajps.12116.

Abadie, A., and J. Gardeazabal. 2003. "The Economic Costs of Conflict: A Case Study of the Basque Country." *American Economic Review* 93, no. 1: 113–132. https://doi.org/10.1257/000282803321455188.

Andersson, J. J. 2019. "Carbon Taxes and Co2 Emissions: Sweden as a Case Study." *American Economic Journal: Economic Policy* 11, no. 4: 1–30. https://doi.org/10.1257/pol.20170144.

Ando, M. 2015. "Dreams of Urbanization: Quantitative Case Studies on the Local Impacts of Nuclear Power Facilities Using the Synthetic Control Method." *Journal of Urban Economics* 85: 68–85. https://doi.org/10.1016/j.jue.2014.10.005.

Arkhangelsky, D., S. Athey, D. A. Hirshberg, G. W. Imbens, and S. Wager. 2021. "Synthetic Difference-In-Differences." *American Economic Review* 111, no. 12: 4088–4118. https://doi.org/10.1257/aer.20190159.

Athey, S., and G. W. Imbens. 2017. "The State of Applied Econometrics: Causality and Policy Evaluation." *Journal of Economic Perspectives* 31, no. 2: 3–32. https://doi.org/10.1257/jep.31.2.3.

Baeyens, A., and T. Goffin. 2015. "European Court of Justice." *European Journal of Health Law* 22, no. 5: 508–516. https://doi.org/10.1163/15718093-12341375.

Balta-Ozkan, N., T. Watson, and E. Mocca. 2015. "Spatially Uneven Development and Low Carbon Transitions: Insights From Urban and Regional Planning." *Energy Policy* 85: 500–510. https://doi.org/10.1016/j.enpol.2015.05.013.

Batel, S. 2020. "Research on the Social Acceptance of Renewable Energy Technologies: Past, Present and Future." *Energy Research & Social Science* 68: 101544. https://doi.org/10.1016/j.erss.2020.101544.

Batini, N., M. Di Serio, M. Fragetta, G. Melina, and A. Waldron. 2022. "Building Back Better: How Big Are Green Spending Multipliers?" *Ecological Economics* 193: 107305. https://doi.org/10.1016/j.ecolecon.2021.107305.

Bertrand, M., E. Duflo, and S. Mullainathan. 2004. "How Much Should We Trust Differences-In-Differences Estimates." *Quarterly Journal of Economics* 119, no. 1: 249–275. https://doi.org/10.1162/003355304772839588.

Bielecki, A., S. Ernst, W. Skrodzka, and I. Wojnicki. 2020. "The Externalities of Energy Production in the Context of Development of Clean Energy Generation." *Environmental Science and Pollution Research* 27, no. 11: 11506–11530. https://doi.org/10.1007/s11356-020-07625-7.

Bouzarovski, S., and N. Simcock. 2017. "Spatializing Energy Justice." *Energy Policy* 107: 640–648. https://doi.org/10.1016/j.enpol.2017.03.064.

Brown, J. P., J. Pender, R. Wiser, E. Lantz, and B. Hoen. 2012. "Ex Post Analysis of Economic Impacts From Wind Power Development In U.S. Counties." *Energy Economics* 34, no. 6: 1743–1754. https://doi.org/10.1016/j.eneco.2012.07.010.

Card, B. D., and A. B. Krueger. 2000. "American Economic Association Minimum Wages and Employment : A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania Author (S): David Card and Alan B. Krueger Source." *American Economic Review* 84, no. 4: 772–793. http://www.jstor.org/stable/2677856.

Card, D. 1990. "The Impact of the Mariel Boatlift on the Miami Labor Market." *ILR Review* 43, no. 2: 245–257. https://doi.org/10.1177/001979399004300205.

Catolico, A. C. C., M. Maestrini, J. C. M. Strauch, F. Giusti, and J. Hunt. 2021. "Socioeconomic Impacts of Large Hydroelectric Power Plants In Brazil: A Synthetic Control Assessment of Estreito Hydropower Plant." *Renewable and Sustainable Energy Reviews* 151: 111508. https://doi.org/10.1016/j.rser.2021.111508.

Cavallo, E., S. Galiani, I. Noy, and J. Pantano. 2013. "Catastrophic Natural Disasters and Economic Growth." *Review of Economics and Statistics* 95, no. 5: 1549–1561. https://doi.org/10.1162/REST_a_00413.

Clarke, D., D. Pailañir, S. Carleton Athey, and G. W. Imbens. 2023. "Synthetic Difference-In-Differences Estimation." *SSRN Electronic Journal* 15907: 1. https://doi.org/10.2139/ssrn.4346540.

Clausen, L. T., and D. Rudolph. 2020. "Renewable Energy for Sustainable Rural Development: Synergies and Mismatches." *Energy Policy* 138: 111289. https://doi.org/10.1016/J.ENPOL.2020.111289.

Coenen, L., T. Hansen, A. Glasmeier, and R. Hassink. 2021. "Regional Foundations of Energy Transitions." *Cambridge Journal of Regions, Economy and Society* 14, no. 2: 219–233. https://doi.org/10.1093/cjres/rsab010.

Colli, F. 2020. "The Eu's Just Transition: Three Challenges and How to Overcome Them." *Egmont Institute* 59: 6. https://about.jstor.org/terms%0Ahttps://www.jstor.org/stable/pdf/resrep24705.pdf?ab_segments=0%2Fbasic_SYC-5187_SYC-5188%2F5187.

Collins, A. R., E. Hansen, and M. Hendryx. 2012. "Wind Versus Coal: Comparing the Local Economic Impacts of Energy Resource Development in Appalachia." *Energy Policy* 50: 551–561. https://doi.org/10.1016/j.enpol.2012.08.001.

Comisión Europea, C. 2022. REPowerEU: Acción europea conjunta por una energía más asequible, segura y sostenible. https://spain.representation.ec.europa.eu/noticias-eventos/noticias-0/repowereu-accion-europea-conjunta-por-una-energia-mas-asequible-segura-y-sostenible-2022-03-08_es.

Copena, D., and X. Simón. 2018. "Wind Farms and Payments to Landowners: Opportunities for Rural Development for the Case of Galicia." *Renewable and Sustainable Energy Reviews* 95: 38–47. https://doi.org/10.1016/j.rser.2018.06.043.

Corden, W. M. 1984. "Booming Sector and Dutch Disease Economics: Survey and Consolidation." *Oxford Economic Papers* 36, no. 3: 359.

Costa, H., and L. Veiga. 2021. "Local Labor Impact of Wind Energy Investment: An Analysis of Portuguese Municipalities." *Energy Economics* 94: 105055. https://doi.org/10.1016/j.eneco.2020.105055.

Coutard, O., and J. Rutherford. 2010. "Energy Transition and City-Region Planning: Understanding the Spatial Politics of Systemic Change." *Technology Analysis & Strategic Management* 22, no. 6: 711–727. https://doi.org/10.1080/09537325.2010.496284.

Cunningham, S., and M. Shah. 2018. "Decriminalizing Indoor Prostitution: Implications for Sexual Violence and Public Health." *Review of Economic Studies* 85, no. 3: 1683–1715. https://doi.org/10.1093/restud/rdx065.

DeAngelo, G., and B. Hansen. 2014. "Life and Death in the Fast Lane: Police Enforcement and Traffic Fatalities." *American Economic Journal: Economic Policy* 6, no. 2: 231–257. https://doi.org/10.1257/pol.6.2.231.

Demeterova, B. 2024. "Assessing Regional Capabilities-Oriented Approaches for European Just and Sustainable Transitions." *Regional Studies* 58, no. 8: 1530–1542. https://doi.org/10.1080/00343404.2023.2242894.

Dijkstra, L., H. Poelman, and A. Rodríguez-Pose. 2020. "The Geography of Eu Discontent." *Regional Studies* 54, no. 6: 737–753. https://doi.org/10.1080/00343404.2019.1654603.

Driffield, N., and D. Hughes. 2003. "Foreign and Domestic Investment: Regional Development or Crowding Out?" *Regional Studies* 37, no. 3: 277–288. https://doi.org/10.1080/0034340032000065433.

Dröes, M. I., and H. R. A. Koster. 2016. "Renewable Energy and Negative Externalities: The Effect of Wind Turbines on House Prices." *Journal of Urban Economics* 96: 121–141. https://doi.org/10.1016/j.jue.2016.09.001.

Dustmann, C., U. Schönberg, and J. Stuhler. 2017. "Labor Supply Shocks, Native Wages, and the Adjustment of Local Employment." *Quarterly Journal of Economics* 132, no. 1: 435–483. https://doi.org/10.1093/QJE/QJW032.

ENRD. 2022. European Network for Rural Development.

EMBER. 2021. Energy & Climate Report for EIA.

ESPON. 2017. Shrinking Rural Regions in Europe. Towards Smart and Innovative Approaches to Regional Development Challenges in Depopulating Rural Regions.

European Commission. 2019. The European Green Deal.

European Commission. 2021. 2021-2027 Cohesion Policy.

EUROSTAT. 2021. Regional Statistics.

Fabra, N., E. Gutierrez, A. Lacuesta, and R. Ramos. 2022. Do Renewables Create Local Jobs? April, 1–62. https://cepr.org/active/publications/discussion_papers/dp.php?dpno=17206.

Ferman, B., C. Pinto, and V. Possebom. 2020. "Cherry Picking With Synthetic Controls." *Journal of Policy Analysis and Management* 39, no. 2: 510–532. https://doi.org/10.1002/pam.22206.

Garvey, A., J. B. Norman, M. Büchs, and J. Barrett. 2022. "A 'Spatially Just' Transition? A Critical Review of Regional Equity In Decarbonisation Pathways." *Energy Research & Social Science* 88: 102630. https://doi.org/10.1016/j.erss.2022.102630.

Gennaioli, N., R. La Porta, F. Lopez-De-Silanes, and A. Shleifer. 2013. "Human Capital AND Regional Development*." *Quarterly Journal of Economics* 128, no. 1: 105–164. https://doi.org/10.1093/qje/qjs050.

Geoghegan, C., and C. O'Donoghue. 2023. "An Analysis of the Social and Private Return to Land Use Change From Agriculture to Renewable Energy Production in Ireland." *Journal of Cleaner Production* 385: 135698. https://doi.org/10.1016/J.JCLEPRO.2022.135698.

Giannakis, E., and A. Bruggeman. 2017. "Determinants of Regional Resilience to Economic Crisis: A European Perspective." *European Planning Studies* 25, no. 8: 1394–1415. https://doi.org/10.1080/09654313.2017.1319464.

Gobillon, L., and T. Magnac. 2016. "Regional Policy Evaluation: Interactive Fixed Effects and Synthetic Controls." *Review of Economics and Statistics* 98, no. 3: 535–551. https://doi.org/10.1162/REST_a_00537.

Green, C. P., J. S. Heywood, and M. Navarro Paniagua. 2020. "Did the London Congestion Charge Reduce Pollution?" *Regional Science and Urban Economics* 84, no. August: 103573. https://doi.org/10.1016/j.regsciurbeco.2020.103573.

Grillitsch, M., and T. Hansen. 2019. "Green Industry Development in Different Types of Regions." *European Planning Studies* 27, no. 11: 2163–2183. https://doi.org/10.1080/09654313.2019.1648385.

Hartley, P. R., K. B. Medlock, T. Temzelides, and X. Zhang. 2015. "Local Employment Impact From Competing Energy Sources: Shale Gas Versus Wind Generation In Texas." *Energy Economics* 49: 610–619. https://doi.org/10.1016/j.eneco.2015.02.023.

Hope, D. 2016. "Estimating the Effect of the EMU on Current Account Balances: A Synthetic Control Approach." *European Journal of Political Economy* 44: 20–40. https://doi.org/10.1016/j.ejpoleco.2016.05.002.

Horiuchi, Y., and A. Mayerson. 2015. "The Opportunity Cost of Conflict: Statistically Comparing Israel and Synthetic Israel." *Political Science Research and Methods* 3, no. 3: 609–618. https://doi.org/10.1017/psrm.2014.47.

van der Horst, D. 2007. "Nimby or Not? Exploring the Relevance of Location and the Politics of Voiced Opinions in Renewable Energy Siting Controversies." *Energy Policy* 35, no. 5: 2705–2714. https://doi.org/10.1016/j.enpol.2006.12.012.

Hosoda, E. 2016. "Resource and Environmental Economics." *Handbook on the History of Economic Analysis* 3: 499–517. https://doi.org/10.4337/9781785365065.00040.

Hu, H., Y. Q. Zhu, S. Y. Li, and Z. Li. 2021. "Effects of Green Energy Development on Population Growth and Employment: Evidence From Shale Gas Exploitation In Chongqing, China." *Petroleum Science* 18, no. 5: 1578–1588. https://doi.org/10.1016/j.petsci.2021.08.013.

International Renewable Energy Agency. 2020. *Renewable Power Generation Costs in 2020*. International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf.

IRENA. 2021. "World Energy Transitions Outlook." *Irena*: 1–54. https://irena.org/publications/2021/March/World-Energy-Transitions-Outlook.

Jenkins, K., D. McCauley, and A. Forman. 2017. "Energy Justice: A Policy Approach." *Energy Policy* 105: 631–634. https://doi.org/10.1016/j.enpol.2017.01.052.

Kahla, F., L. Holstenkamp, J. R. Müller, H. Degenhart Mai, and H. Degenhart. 2017. Entwicklung und Stand von Bürgerenergiegesellschaften und Energiegenossenschaften in Deutschland Development and State of Community Energy Companies and Energy Cooperatives in Germany. www.leuphana.de/businessandlaw.

Kerr, R. B., T. Hasegawa, R. Lasco, et al. 2022. "Food, Fibre, and Other Ecosystem Products. Climate Change 2022: Impacts, Adaptation and Vulnerability." Working Group II Contribution to the IPCC Sixth Assessment Report, 1–286.

Kim, M. K., and T. Kim. 2016. "Estimating Impact of Regional Greenhouse Gas Initiative on Coal to Gas Switching Using Synthetic Control Methods." *Energy Economics* 59: 328–335. https://doi.org/10.1016/j.eneco.2016.08.019.

Kleven, H. J., C. Landais, and E. Saez. 2013. "Taxation and International Migration of Superstars: Evidence From the European Football Market." *American Economic Review* 103, no. 5: 1892–1924. https://doi.org/10.1257/aer.103.5.1892.

Lambert, R. J., and P. P. Silva. 2012. "The Challenges of Determining the Employment Effects of Renewable Energy." *Renewable and Sustainable Energy Reviews* 16, no. 7: 4667–4674. https://doi.org/10.1016/J.RSER.2012.03.072.

Lan, W., X. Chen, T. Zou, and C. L. Tsai. 2021. "Imputations for High Missing Rate Data in Covariates via Semi-Supervised Learning Approach." *Journal of Business & Economic Statistics* 40: 1282–1290. https://doi.org/10.1080/07350015.2021.1922120.

Lehmann, P., E. Gawel, J. N. Meier, M. J. Reda, F. Reutter, and S. Sommer. 2024. "Spatial Distributive Justice Has Many Faces: The Case of Siting Renewable Energy Infrastructures." *Energy Research & Social Science* 118: 103769. https://doi.org/10.1016/j.erss.2024.103769.

Lehr, U., C. Lutz, and D. Edler. 2012. "Green Jobs? Economic Impacts of Renewable Energy In Germany." *Energy Policy* 47: 358–364. https://doi.org/10.1016/j.enpol.2012.04.076.

Leonard, A., A. Ahsan, F. Charbonnier, and S. Hirmer. 2022. "The Resource Curse in Renewable Energy: A Framework for Risk Assessment." *Energy Strategy Reviews* 41, no. 2: 100841. https://doi.org/10.1016/j.esr.2022.100841.

Leroutier, M. 2022. "Carbon Pricing and Power Sector Decarbonization: Evidence From the UK." *Journal of Environmental Economics and Management* 111: 102580. https://doi.org/10.1016/j.jeem.2021.102580.

Li, F. G. N., S. Pye, and N. Strachan. 2016. "Regional Winners and Losers in Future UK Energy System Transitions." *Energy Strategy Reviews* 13–14: 11–31. https://doi.org/10.1016/j.esr.2016.08.002.

Lindo, J. M., and A. Packham. 2017. "How Much Can Expanding Access to Long-Acting Reversible Contraceptives Reduce Teen Birth Rates?" *American Economic Journal: Economic Policy* 9, no. Issue 3: 348–376. https://doi.org/10.1257/pol.20160039.

Madanipour, A., M. Shucksmith, and E. Brooks. 2022. "The Concept of Spatial Justice and the European Union's Territorial Cohesion." *European Planning Studies* 30, no. 5: 807–824. https://doi.org/10.1080/09654313.2021.1928040.

Månsson, A. 2015. "A Resource Curse for Renewables? Conflict and Cooperation in the Renewable Energy Sector." *Energy Research and Social Science* 10: 1–9. https://doi.org/10.1016/j.erss.2015.06.008.

Martínez-Filgueira, X., D. Peón, and E. López-Iglesias. 2017. "Intra-Rural Divides and Regional Planning: An Analysis of a Traditional Emigration Region (Galicia, Spain)." *European Planning Studies* 25, no. 7: 1237–1255. https://doi.org/10.1080/09654313.2017.1319465.

Mattmann, M., I. Logar, and R. Brouwer. 2016. "Wind Power Externalities: A Meta-Analysis." *Ecological Economics* 127: 23–36. https://doi.org/10.1016/j.ecolecon.2016.04.005.

Mauritzen, J. 2020. "Will the Locals Benefit?" *Energy Policy* 142: 111489. https://doi.org/10.1016/J.ENPOL.2020.111489.

Međugorac, V., and G. Schuitema. 2023. "Why Is Bottom-Up More Acceptable Than Top-Down? A Study on Collective Psychological Ownership and Place-Technology Fit in the Irish Midlands." *Energy Research & Social Science* 96: 102924. https://doi.org/10.1016/j.erss.2022.102924.

Montalvo, J. G. 2011. "Voting after the Bombings: A Natural Experiment on the Effect of Terrorist Attacks on Democratic Elections." *Review of Economics and Statistics* 93, no. 4: 1146–1154. https://doi.org/10.1162/REST_a_00115.

Mueller, J. T., and M. M. Brooks. 2020. "Burdened by Renewable Energy? A Multi-Scalar Analysis of Distributional Justice and Wind Energy In the United States." *Energy Research & Social Science* 63: 101406. https://doi.org/10.1016/j.erss.2019.101406.

Mulvaney, K. K., P. Woodson, and L. S. Prokopy. 2013. "A Tale of Three Counties: Understanding Wind Development In the Rural Midwestern United States." *Energy Policy* 56: 322–330. https://doi.org/10.1016/j.enpol.2012.12.064.

Munasib, A., and D. S. Rickman. 2015. "Regional Economic Impacts of the Shale Gas and Tight Oil Boom: A Synthetic Control Analysis." *Regional Science and Urban Economics* 50: 1–17. https://doi.org/10.1016/j.regsciurbeco.2014.10.006.

Munday, M., G. Bristow, and R. Cowell. 2011. "Wind Farms In Rural Areas: How Far Do Community Benefits From Wind Farms Represent a Local Economic Development Opportunity?" *Journal of Rural Studies* 27, no. 1: 1–12. https://doi.org/10.1016/j.jrurstud.2010.08.003.

O'Sullivan, K., O. Golubchikov, and A. Mehmood. 2020. "Uneven Energy Transitions: Understanding Continued Energy Peripheralization In Rural Communities." *Energy Policy* 138: 111288. https://doi.org/10.1016/J.ENPOL.2020.111288.

OECD. 2012. Linking Renewable Energy to Rural Development Executive Summary. http://www.oecd.org/regional/linkingrenewableenergytoruraldevelopment.htm.

OECD. 2021. "The Inequalities- Environment Nexus: Towards A People-Centred Green Transition." *OECD Green Growth Papers, OECD Publi* 1: 11–74. https://uoelibrary.idm.oclc.org/login?url=https://www.proquest.com/working-papers/inequalities-environment-nexus-towards-people/docview/2528502867/se-2?accountid=10792%0Ahttps://resolver.ebscohost.com/openurl?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8.

Palombi, S., R. Perman, and C. Tavéra. 2015. "Regional Growth and Unemployment In the Medium Run: Asymmetric Cointegrated Okun's Law for UK Regions." *Applied Economics* 47, no. 57: 6228–6238. https://doi.org/10.1080/00036846.2015.1068922.

Pavlínek, P. 2004. "Regional Development Implications of Foreign Direct Investment in Central Europe." *European Urban and Regional Studies* 11, no. 1: 47–70. https://doi.org/10.1177/0969776404039142.

Pellegrini, L., L. Tasciotti, and A. Spartaco. 2021. "A Regional Resource Curse? A Synthetic-Control Approach to Oil Extraction in Basilicata, Italy." *Ecological Economics* 185: 107041. https://doi.org/10.1016/j.ecolecon.2021.107041.

Perez-Sindin, X. S., J. Lee, and T. Nielsen. 2022. "Exploring the Spatial Characteristics of Energy Injustice: A Comparison of the Power Generation Landscapes in Spain, Denmark, and South Korea." *Energy Research & Social Science* 91: 102682. https://doi.org/10.1016/j.erss.2022.102682.

Perpiña Castillo, C., F. Batista e Silva, and C. Lavalle. 2016. "An Assessment of the Regional Potential for Solar Power Generation In

Eu-28." *Energy Policy* 88: 86–99. https://doi.org/10.1016/J.ENPOL.2015.10.004.

Pinotti, P. 2015. "The Economic Costs of Organised Crime: Evidence from Southern Italy." *Economic Journal* 125, no. 586: F203–F232. https://doi.org/10.1111/ecoj.12235.

Pires Manso, J. R., A. J. Fernandes de Matos, and C. C. M. Carvalho. 2015. "Determinants of Regional Growth in Portugal: An Empirical Analysis." *ECONOMICS & SOCIOLOGY* 8, no. 4: 11–31. https://doi.org/10.14254/2071-789X.2015/8-4/1.

Punt, M. B., T. Bauwens, K. Frenken, and L. Holstenkamp. 2022. "Institutional Relatedness and the Emergence of Renewable Energy Cooperatives in German Districts." *Regional Studies* 56, no. 4: 548–562. https://doi.org/10.1080/00343404.2021.1890708.

Rickman, D., and H. Wang. 2020. "What Goes up Must Come Down? The Recent Economic Cycles of the Four Most Oil and Gas Dominated States in the US." *Energy Economics* 86: 104665. https://doi.org/10.1016/j.eneco.2020.104665.

del Río, P., and M. Burguillo. 2009. "An Empirical Analysis of the Impact of Renewable Energy Deployment on Local Sustainability." *Renewable and Sustainable Energy Reviews* 13, no. 6–7: 1314–1325. https://doi.org/10.1016/j.rser.2008.08.001.

Roberts, P. 2003. "Sustainable Development and Social Justice: Spatial Priorities and Mechanisms for Delivery." *Sociological Inquiry* 73, no. 2: 228–244. https://doi.org/10.1111/1475-682X.00054.

Rodríguez-Pose, A. 2018. "The Revenge of the Places That Don't Matter (And What to Do about It)." *Cambridge Journal of Regions, Economy and Society* 11, no. 1: 189–209. https://doi.org/10.1093/cjres/rsx024.

Rodríguez-Pose*, A., and U. Fratesi†. 2004. "Between Development and Social Policies: The Impact of European Structural Funds in Objective 1 Regions." *Regional Studies* 38, no. 1: 97–113. https://doi.org/10.1080/0034340031000163222 6.

Runst, P., and A. Thonipara. 2020. "Dosis Facit Effectum Why the Size of the Carbon Tax Matters: Evidence From the Swedish Residential Sector." *Energy Economics* 91: 104898. https://doi.org/10.1016/j.eneco.2020.104898.

Sardaro, R., N. Faccilongo, and L. Roselli. 2019. "Wind Farms, Farmland Occupation and Compensation: Evidences From Landowners' Preferences Through a Stated Choice Survey in Italy." *Energy Policy* 133: 110885. https://doi.org/10.1016/j.enpol.2019.110885.

Sasse, J. P., and E. Trutnevyte. 2020. "Regional Impacts of Electricity System Transition in Central Europe Until 2035." *Nature Communications* 11, no. 1: 4972. https://doi.org/10.1038/s41467-020-18812-y.

Sayan, R. C. 2019. "Exploring Place-Based Approaches and Energy Justice: Ecology, Social Movements, and Hydropower in Turkey." *Energy Research & Social Science* 57: 101234. https://doi.org/10.1016/j.erss.2019.101234.

Slattery, M. C., E. Lantz, and B. L. Johnson. 2011. "State and Local Economic Impacts From Wind Energy Projects: Texas Case Study." *Energy Policy* 39, no. 12: 7930–7940. https://doi.org/10.1016/j.enpol.2011.09.047.

Smith, B. 2015. "The Resource Curse Exorcised: Evidence From a Panel of Countries." *Journal of Development Economics* 116: 57–73. https://doi.org/10.1016/j.jdeveco.2015.04.001.

Soja, E. W. 2010. *Seeking Spatial Justice*. University of Minnesota Press. https://doi.org/10.5749/minnesota/9780816666676.001.0001.

Sovacool, B. K. 2017. "Contestation, Contingency, and Justice in the Nordic Low-Carbon Energy Transition." *Energy Policy* 102: 569–582. https://doi.org/10.1016/j.enpol.2016.12.045.

Sterlacchini, A. 2008. "R&D, Higher Education and Regional Growth: Uneven Linkages Among European Regions." *Research Policy* 37, no. 6–7: 1096–1107. https://doi.org/10.1016/j.respol.2008.04.009.

Thissen, M., M. Lankhuizen, F. G. van Oort, B. Los, and D. Diodato. 2018. "EUREGIO: The Construction of a Global IO Database With Regional Detail for Europe for 2000-2010." *Tinbergen Institute Discussion Paper, No. TI 201* : 1.

Tverijonaite, E., A. D. Sæþórsdóttir, R. Ólafsdóttir, and C. M. Hall. 2022. "How Close Is Too Close? Mapping the Impact Area of Renewable Energy Infrastructure on Tourism." *Energy Research & Social Science* 90: 102574. https://doi.org/10.1016/J.ERSS.2022.102574.

UN. 2016. "United Nations Paris Agreement on Climate Change." In *Treaty Doc*, 27–52. http://bigpicture.unfccc.int/#content-the-paris-agreemen.

Wang, X., and K. Lo. 2021. "Just Transition: A Conceptual Review." *Energy Research & Social Science* 82: 102291. https://doi.org/10.1016/j.erss.2021.102291.

Weck, S., A. Madanipour, and P. Schmitt. 2022. "Place-Based Development and Spatial Justice." *European Planning Studies* 30, no. 5: 791–806. https://doi.org/10.1080/09654313.2021.1928038.

van Wijnbergen, S. 1984. "The 'Dutch Disease': A Disease After All ?" *Economic Journal* 94, no. 373: 41–55. http://www.jstor.org/stable/2232214.

Xiang, D., and C. Lawley. 2019. "The Impact of British Columbia's Carbon Tax on Residential Natural Gas Consumption." *Energy Economics* 80: 206–218. https://doi.org/10.1016/j.eneco.2018.12.004.

Zerrahn, A. 2017. "Wind Power and Externalities." *Ecological Economics* 141: 245–260. https://doi.org/10.1016/j.ecolecon.2017.02.016.

Zheng, X. P. 2007. "Economies of Network, Urban Agglomeration, and Regional Development: A Theoretical Model and Empirical Evidence." *Regional Studies* 41, no. 5: 559–569. https://doi.org/10.1080/00343400701281774.

Zou, B. 2018. "The Local Economic Impacts of Military Personnel." *Journal of Labor Economics* 36, no. 3: 589–621. https://doi.org/10.1086/696141.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.