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Economic and territorial integration of renewables in rural areas: Lessons from a long-term perspective

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ABSTRACT

The current awareness of climate change and its consequences has motivated international institutions and states to make sustainable development a central goal, promoting a process of energy transition towards low-carbon economies. This process entails an increase in the share of renewables in the energy mix, with wind power currently being the renewable source that produces the most energy, and whose growth is accelerating, both nationally and globally. The development of the associated infrastructures, many often in rural areas, has been seen either as a blessing or a curse, sometimes conceived as a historic opportunity to boost economic growth and employment, and sometimes as a threat that prevents future alternative developments.

In this context, this work evaluates the socio-economic and demographic effects of wind power installations, in the short and long term, on the rural territory of the Campo de Belchite county (Aragon, Spain). We analyze the compatibility of rural development and environmental goals retrospectively, using a novel approach in this field, the Synthetic Control Method. Our results highlight that the compatibility of socio-economic, demographic, and environmental objectives can be difficult to achieve in rural territories, with negative effects in terms of rural population and only temporary job creation. Positive economic outcomes are found but they are not immediate. Our work brings insights and guidelines for the management of wind farms that must be linked to the territory and to its population to reach a just energy transition.

1. Introduction

There is a broad consensus among governments and society that climate change is one of the most important challenges humanity faces in achieving sustainable and inclusive development, as demonstrated by the signing of the Paris Agreements (UN, 2015) and the Agenda 2030 for sustainable development (UNFCCC, 2015). The process of decarbonization in the economies of developed countries is key to progressing towards these objectives. This process of energy transition entails a change from electricity production based on non-renewable energy sources in favour of renewables, such as hydroelectric and wind power (Mattmann et al., 2016). Wind energy is the second most important source of energy worldwide in terms of electricity generation, with a growing trend. In 2017, wind energy generated 4.6% of global electricity generation (EIA, 2020) and this has undergone a process of continuous expansion worldwide since the beginning of the 21st century, boosted by different national and regional policies, including regulation, fiscal expenditure, subsidies, and infrastructure provision, as well as other complementary services. As a result, the increase in the cumulative installed capacity of wind energy has enjoyed exponential growth, and it is predicted to continue into the future (GWEC, 2020).

Spain has participated in this international trend. In 2019, the Strategic Framework for Energy and Climate (Council of Ministers, 22/02/2019) was enacted, in line with international agreements, which integrates three essential pillars: the Integrated National Energy and Climate Plan (NECP), with a 2021–2030 horizon, the draft bill on Climate Change and Energy Transition, and the Just Transition Strategy. Some of the measures included in the NECP aim to achieve a 42% share of renewables in final energy use, and 74% of renewables in electricity generation. The first draft of the Climate Change and Energy Transition Law aims to achieve emissions neutrality by 2050, by taking advantage of the economic reactivation in the face of COVID-19, while the Just Transition Strategy seeks to ensure that people and regions take full advantage of opportunities by influencing greater social and territorial cohesion. To achieve these objectives, wind energy has played a key role in the energy transition process of the Spanish economy. Currently,

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Spain is fifth in the world in terms of the greatest accumulated and installed wind power capacity, which allows it to cover 19% of electricity demand. Total installed capacity amounts to 23,484 MW, generating 0.31% of Spanish Gross Domestic Product (GDP) and 22,578 jobs (AEE, 2019). The environmental benefits are a key element in the decarbonisation strategy of the Western economies. However, the installation and exploitation are associated with a set of externalities, potentially positive or negative, which are economic, social, demographic, and environmental in nature, with more local impacts on the specific territory in which the projects are developed.

In particular, the European Commission (COM, 22 of 30 January 2019) recognises that the ecological transition to more sustainable economies can lead to significant positive effects on social and employment outcomes and the well-being of citizens. Nevertheless, temporary frictions may also be generated in the labour market, requiring a reallocation of jobs between sectors and regions, and affecting them heterogeneously. Consequently, the evaluation of these local socio-economic effects adds territorial, spatial, and social elements, which are fundamental in the study and assessment of a fair transition process.

In this context, the main objective of this work is to address a critical discussion on the short- and long-term impacts of the installation of renewables infrastructures in rural areas. In particular, we evaluate the associated economic, demographic, and employment effects that wind power installation has on the relevant rural territories.

Empirically, we focus on the Ebro Valley, one of the most important wind-farm regions in Spain. Within this basin, Aragon is one of the leaders of wind power installed in recent years. Due to its representativeness and its geographical conditions within Aragon, we choose the county of Campo de Belchite, a wind-rich region that represents 10% of the total installed power in Aragon (306,455 MW). Prior studies have examined the impacts of wind power installations in rural territories (Zerrahn, 2017). Brown et al. (2012) found positive results in county personal income in U.S counties; Kahn (2013) documented positive results for county residents from recent place-based investments in wind farms in West Texas. Mulvaney et al. (2013) found widespread community-level acceptance of wind energy and wind farms in the rural Midwestern United States. A recent review of existing studies is shown in Shoeib et al. (2021), who found that wind-development tax income improved community services without any noticeable increase in required community services or the cost of living.

This work builds on these works by applying the methodology of the Synthetic Control Method (SCM), initially developed by Abadie and Gardeazabal (2003), to the analysis of the soecioeconomic long term effects of wind power installations in rural territories. To the best of our knowledge, this is the first application of this methodology to the evaluation of renewables, which allows the effects of some type of intervention (public or private) to be calculated retrospectively, and is applicable to any treatment unit (country, region, county, etc.). Broadly speaking, we evaluate the impacts of wind power installations on rural areas, ex post, by comparing the effects if these installations were not developed. This methodology has been widely applied in the literature to other events. For instance, the seminal paper of Abadie and Gardeazabal (2003) applies this technique to analyze the economic impact of ETA terrorism in the Basque Country (Spain), showing that GDP per capita there fell by around 10% in relation to the region of synthetic control without terrorism. Subsequently, this approach has been used to evaluate other public issues, such as the economic effect of other armed conflicts (Gardeazabal and y Vega-Bayo, 2016), as well as to analyze the effect of gun laws on homicides in the United States (Guettabi and Munasib, 2017). Moreover, this methodology has been widely used in different contexts. Some examples are found in Abadie et al. (2010), who estimate the effect of tobacco controls in California in 1988; Abadie et al. (2015), who analyze the economic impact of German Reunification in 1990; and the work of Hope (2016), who evaluates the effect of the European Monetary Union on the current accounts of its member states. The works of Munasib and Rickman (2015) and Rickman and Wang (2020) studies the territorial economic impacts of development of oil and gas production with this methodology. Recently, the methodology has been used to assess the effect of infrastructure on local development, as in the case of the effect on tourism of a new airport in a region of Germany in Doerr et al. (2020), and the effect of price fixing on fuel prices (Becker et al., 2021). The methodology has also been extended to the study of environmental impacts in Rosado-Anastacio (2018), Green et al. (2020), Runst and Thonipara (2020), Kim and Kim (2016), Xiang and Lawley (2019) and Cole et al. (2020).

In sum, this paper contributes to current studies of rural development and wind power installations in two ways. First, to the best of our knowledge, this is the first time that the SCM methodology is used at such a disaggregated level as the regional/county level, and for the evaluation of impacts related to renewables. Second, the economic, social (jobs) and demographic effects, in the short and long term, of the installation of wind farms are evaluated retrospectively. Specifically, we evaluate the effects on a set of specific variables such as value-added per capita, total employment and population, in order to capture the effect of wind energy on rural development. Our findings shed light on discussions about wind power development and rural development as the deployment of renewable energies is expected to be continued in the future, both for the region under study and for other regions. Moreover, our research goes beyond a specific case study to discuss the compatibility of environmental, economic, and social impacts of wind farms. Specifically, our results highlight negative effects in terms of rural population evolution and temporary jobs creation (similar to the results found by Costa and Veiga (2021) for the municipalities of Portugal). However, positive economic (income) outcomes are found, but they are not immediate. Our work brings insights for policymakers, suggesting that the management of wind farms must be linked to the specifics of the territory and its population to reach a just energy transition.

The rest of the work is structured as follows. In Section 2, the wind energy sector in Aragon and the Campo de Belchite county is contextualised. Section 3 presents the methodology and data. Section 4 presents the main results and Section 5 discuss our findings. Section 6 offers a conclusion and policy recommendations.

2. Background: Wind energy in Aragon

The wind energy sector is key to the generation of renewables in Spain. Aragon was the fifth Autonomous Community in terms of the percentage of accumulated wind power in 2018, representing 12.08% of Spain's market share. In addition, Aragon was the region that installed the most power during 2019 and 2020 (AEE, 2019). Currently, Aragon has 155 wind farms, including 2539 turbines and a power of 3420.12 MW (MITECO, 2020). Within Aragon, it is worth noting that 80% of the wind farms and 75% of the installed power is concentrated in the province of Zaragoza. Specifically, in 2008, Zaragoza was the second province in Spain with the most installed power (MW) (Galdós and y Madrid, 2009).

Thus, Aragon has become one of the most attractive regions for the installation of wind farms (henceforth, PE). Its geographical conditions, especially in the area of the Ebro Valley where the wind is very often constant, demonstrate its importance as a source of wind energy (Espejo, 2006). However, economic conditions in Aragon do not seem to benefit from its geography. As we will see, the economic effects of this energy source will be quite reduced, due to a lack of backward linkages and low importance of the industrial sector associated with wind energy. Namely, the installation of wind farms has not been accompanied by the installation of auxiliary industries for the assembly of wind turbines or the production of turbine blades, there by reducing the capacity to generate employment and value-added (Galdós and Madrid, 2009). Specifically, there are only five companies dedicated to the manufacture of components and the assembly of wind turbinesin in Aragon (AEE, 2019), which limits the effects of drawing in and boosting a sector that is as dynamic as it is strategic. Fig. 1 displays the historical evolution of wind energy in Aragon. We observe that the main installation and production period of this renewable energy took place in the second half of the 1990s. The initial impulse increased progressively until the beginning of the economic crisis in 2008, where it stagnated for about nine years, both in the installation of wind farms and in the total power (MW) generated. In recent years, accelerated growth has been observed, almost as if from a shock, with wind energy in Aragon gaining new momentum. This new cycle is largely due to the allocation of new wind farms through public auctions, used as an awarding and incentive mechanism in Spain. These implementations of wind farms took place between 2019 and 2020, and a condition, to be satisfied by the bidders, was that the power should be on line before the year 2020 (REE, 2020).

In this context, we analyze the socio-economic effects associated with the first wave of wind power installations (1998–2005). But a second wave of investments in wind farms has recently begun and will expand over the next few years. Thus, our findings may be very informative for the scope of local and rural development for the territories affected.

Within Aragon, we select the installation of wind farms in the Campo de Belchite county, which includes 9 wind farms, with 154 windmills, producing total power of 306.45 MW. This power accounts for 10% of the total installed power in Aragon. Note that the historical trend that characterises the evolution of installed power and wind energy production in Aragon is also reflected in Campo de Belchite, because the first wind farms were installed there between 2004 and 2005, attaining around 22% of the total installed power in Aragon in those years. The installation of six new wind farms has been authorised in 2020, it thus is expected that these numbers could increase in the coming years (BOA, 2021; BOE, 2021a; BOE, 2021b). Moeover, as commented, this process is not only taking place in Aragon, but throughout the whole of Spain (NECP).

The relevance of this work lies in analysing the economic and demographic effects that the installation of wind farms has had on the territory, both in the short and long term. This assessment will help to anticipate the potential impacts of future installations, and foster a discussion of energy and territorial policies, aimed at achieving an economic, social, and environmental dividend with the least number of incompatibilities.

3. Methodology

In this work, the Synthetic Control Method is used, as proposed by Abadie and Gardeazabal (2003). This methodology aims to build a synthetic control unit as a convex combination of several control units. The weights that identify the synthetic control unit are those that best approximate the characteristics of the treatment unit and the control unit during the pre-intervention period. The post-intervention result of the synthetic control unit is used to estimate the result that would be observed for the treated unit in the absence of intervention, which allows the causal effect of the intervention to be captured.

In other words, the treatment's effect will be the difference between the observed path for the treated unit and the estimated path for the control group, which approximates the treated unit under the counterfactual that the treatment did not exist.

Abadie et al. (2010) present a formal and technical discussion of the theoretical properties of the synthetic control method, which are summarised here. Specifically, the authors calculate the synthetic control estimator using an econometric model that generalizes the differences-in-differences model, a methodology widely used in the literature (Khandker et al., 2010; Gertler et al., 2011).

Formally, based on observation of units $j = 1, \ldots, J + 1$ for time periods $t = 1, \ldots, T$, it is assumed that the first unit represents the one in which the intervention to be studied occurs, so we have J control units additionally that can calculate the synthetic control unit. The intervention takes place in the period $T_0 + 1$, so the periods $1, 2, \ldots T_0$ represent the pre-intervention period and $T_0 + 1, T_0 + 2, \ldots T$ represent the post-intervention period.

Two potential outcomes are defined, Y_{it}^{N} is the outcome we observe for unit i in period t if unit i was not exposed to intervention, and Y_{it}^{I} refers to the observed outcome of unit i, which was exposed to intervention. The objective is to estimate the effect of the intervention on the treated unit in the post-intervention period. This effect can be formally defined as the difference between the two defined potential outcomes, $\alpha_{it} = Y_{it}^{I} - Y_{it}^{N}$ for the periods $T_0 + 1, T_0 + 2, \ldots T$. In consequence, the synthetic control method needs to construct a synthetic control group, in such a way that it can be used as a reasonable estimation of the unobservable result.

Specifically, the objective is to build a synthetic control group that is as similar as possible to the treated unit in the relevant characteristics of the pre-intervention period. Formally, we define U_i as a (r x 1) vector of

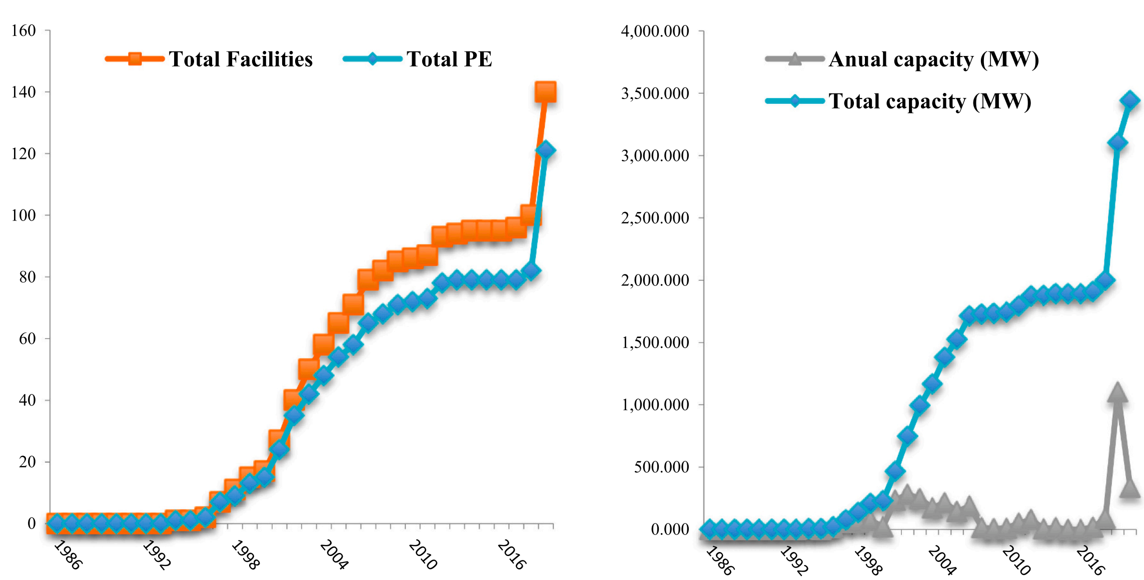

Fig. 1. Accumulated annual evolution of the number of installations, wind farms, and power and annual evolution of installed power. Source: Data collected from MITECO (2020).

observed variables of each unit. These variables are usually a set of predictors of the variable under study. We also define a $(T_0 \times 1)$ vector, K $= (k_1, \ldots, k_{T0})'$, that denotes some linear combination of pre-intervention outcomes: $\overline{Y}_i^K = \sum_{s=1}^{T_0} k_s Y_{is}$. Linear combinations of pre-intervention outcomes are used to control for non-observable factors, i.e. those characteristics that may affect results but are not taken into account and whose effects may vary over time. *M* number of combinations of the pre-intervention results can be included, if M $\leq T_0$ so that unobservable factors can be controlled.

To construct our synthetic control group, we define a $(J\text{x}1)$ vector of weights $W = (w_2, \ldots, w_{J+1})'$ where $w_j \geq 0$ for j = 2, …, J + 1 and $w_2 + \ldots + w_{J+1} = 1$. Each W then represents one particular weighted average of control units and therefore one possible synthetic control unit. Abadie and Gardeazabal (2003) and Abadie et al. (2010) propose choosing those weights W^* that best approximate the synthetic control group to the treatment unit in relation to the characteristics that affect the results, in the period prior to the intervention U_i and to the M linear combinations of the results prior to the intervention $\overline{Y}_i^{K_1}, \ldots, \overline{Y}_i^{K_M}$.

Formally, we select $W^* = (w_2^*, \ldots, w_{J+1}^*)$, such that $\sum_{j=2}^{J+1} w_j^* \overline{Y}_j^{K_1} = Y_1^{K_1} \ldots \sum_{j=2}^{J+1} w_j^* \overline{Y}_j^{K_M} = Y_1^{K_M}$ y $\sum_{j=2}^{J+1} w_j^* U_J = U_1$. Therefore we get that:

$$\widehat{\alpha}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \quad (1)$$

being an estimator of the causal effect in the periods after the intervention. The formal discussion of the properties of this estimator can be found in detail in Abadie et al. (2010).

In empirical applications, it may be the case that there is no set of weights that precisely meets condition $\sum_{j=2}^{J+1} w_j^* \overline{Y}_j^{K_1} = Y_1^{K_1} \ldots \sum_{j=2}^{J+1} w_j^* \overline{Y}_j^{K_M} = Y_1^{K_M}$ and $\sum_{j=2}^{J+1} w_j^* U_J = U_1$, because the characteristics of the treatment unit $\left(U_1, \overline{Y}_1^K, \ldots, \overline{Y}_1^{K_M}\right)$ are outside the convex set of characteristics of the control units $\left\{\left(U_2, \overline{Y}_2^{K_1}, \ldots, \overline{Y}_2^{K_M}\right), \ldots, \left(U_{J+1}, \overline{Y}_{J+1}^{K_1}, \ldots, \overline{Y}_{J+1}^{K_M}\right)\right\}$. In these cases, those weights are chosen that best corroborate the conditions of identity between the treatment and control groups. Therefore, we should observe and check how similar the synthetic control group and the treated group are.

To implement the estimator under this methodology, we need to define the distance between the synthetic control unit and the treated unit. To this end, the characteristics of the unit exposed to intervention are combined in a $(k\text{x}1)$ matrix $X_1 = \left(U_1', \overline{Y}_1^K, \ldots, \overline{Y}_1^{K_M}\right)'$ and the values of the same characteristics of the control units, in a $(k \times J)$ matrix $X_0 = \left(U_j', \overline{Y}_j^K, \ldots, \overline{Y}_j^{K_M}\right)'$. Where $k = r + M$.

To achieve the most similar synthetic control group, we must obtain the W^* vector that minimizes the distance, $\|X_1 - X_0 W\|$ between X_1 and $X_0 W$ subject to the restrictions of the weights. Specifically, it is resolved for that W* that minimizes:

$$\|X_1 - X_0 W\|_v = \sqrt{(X_1 - X_0 W)} \acute{V} (X_1 - X_0 W) \quad (2)$$

where **V** is defined as a symmetrical, semi-positive $(k \times k)$ matrix. This matrix is introduced to allow the selection of different weights to the variables in X_0 and X_1 depending on their predictive power. An optimal **V** assignment is one that minimizes the mean square error of the synthetic control estimator, which is the expectation of $(Y_1 - Y_0 W^*)'(Y_1 - Y_0 W^*)$.

Abadie and Gardeazabal (2003) and Abadie et al. (2010) propose choosing **V*** among all the positive and diagonal defined matrices that minimise the mean square error of prediction (MSPE) of the variable to be analysed, in all the periods prior to the intervention. With Z_1 being a $(Tp \times 1)$ vector with the values of the results of the treatment unit for the periods prior to the intervention, and Z_0 the analogous $(Tp \times J)$ matrix for the control units, where Tp is the number of periods prior to the intervention over which we are minimizing the MSPE, with $1 \leq Tp \leq T_0$. Therefore, we choose the V* that minimizes:

$$argmin_{V \in v} (Z_1 - Z_0 W^*(V))' (Z_1 - Z_0 W^*(V)) \quad (3)$$

where v is the set of defined positive and diagonal matrices and the weights for the synthetic control group are given by W*. In the definitive, a nested optimization problem is solved that minimizes eq. (3), for W*(V) subject to eq. (2).

Finally, Abadie et al. (2010) and Bertrand et al. (2004) propose inference techniques for this methodology, the so-called "*placebo studies*". The underlying principle proposes to apply the method of synthetic control by reallocating the time of the intervention or the control and treatment groups (using a control unit, where the intervention did not occur). Once we have observed these new effects, we can compare them with the effects estimated for the years and units, where the intervention actually occurred. This comparison is informative about the uniqueness, or not, of the magnitude of the estimated effect on the unit exposed to the intervention, where, if the method has worked correctly, it should always give greater effects on the unit exposed, than on any other reorganization we propose. Other applications of these tests can be found in Abadie and Gardeazabal (2003) and Abadie et al. (2015).

For our empirical application, the treatment unit is the Campo de Belchite county, since this is the region in which we analyze the socioeconomic effects of the installation of wind energy. The variables under study are population, gross value-added per capita and employment. The control group, which will be the potential candidates to form the synthetic control group, will be the rest of the Aragon counties (33).[1] The year selected as the year of intervention is 2006, because the last wind farm began installation in December 2005, which seems an appropriate point to start evaluating its socioeconomic effects. As shown in Fig. 1, a new stage of expansion of wind energy in Aragon will begin in 2019. It is not until 2020, when a new wind farm is installed in the county under study. For these reasons, it is decided to evaluate the socioeconomic effects until 2019, where only the effects of the first wave of wind energy are considered. That is, our models estimate causal effects from 2006 to 2019, when there was practically no expansion of wind energy in Aragón.

As we have mentioned, a central objective underlying this methodology is to be able to represent, as accurately as possible, the economic, social, and geographical structure of the Campo de Belchite county in the period before the intervention.[2] All variables are chosen as potential determinants of rural development. The objective is to capture the economic, social and natural capital of each region, a determining factor in the greater or lesser development of the rural world. To that end and following literature, the variables/characteristics selected have been grouped into four large blocks: First, we include a set of demographic variables to capture the regional demographic structure (see Sánchez-Zamora et al., 2014; Rodríguez-Pose and Hardy, 2015). The variables used are *Population* (1998–2019), *Ageing Index* (2003–2019), *Average Age* (2003–2019) and *Foreign Population* (1998–2019). Another common group of key variables to approximate the economic structure of the regions are (following Teräs et al., 2015; Goerlich and Reig, 2020; Agarwal et al., 2009): *Gross Value Added* (2000–2018), *Gross Value Added* per capita (2000–2018), *Building Licences* (2000–2018) and a Human Capital proxy, such as the *number of schools in each region*

[1] The two counties with the most installed wind energy are eliminated. This exclusion is made so that they do not interfere in the calculation of the synthetic control group, and do not raise possible problems of causality (since they are also exposed to the intervention).

[2] Note that the objective of this methodology is not focused on explaining causality between variables, but to develop a synthetic indicator that best approximates the treatment group through a set of variables.

(2001–2018), which have been taken into account (Fratesi and Perucca, 2018; Agarwal et al., 2009). Regarding the impact of the wind energy installation on the labour market, we include the following indicators (as Agarwal et al., 2009; Sánchez-Zamora et al., 2014): *Total Employment* (2000–2018), *Stability Rate* (2005–2019) and *unemployment rate* (2005–2019). Finally, a series of geographical variables are included (see Agarwal et al., 2009; Laurin et al., 2020): *Population density* (1998–2019), *percentage of urbanized land* (2002–2019) and *the average temperature of each region in the year 2000*. All these variables are available at Aragon Institute of Statistics (IAEST, 2020).

Table 1 shows the set of variables used in each model. Columns (1) and (2) show the values for the region under study and for Aragon before the installation of wind farms. In each model, the average of the pre-intervention period of the outcome variable is used as the explanatory variable (similar to Abadie and Gardeazabal, 2003; Abadie et al., 2010). See a discussion about the inclusion of the average outcome variable in Kaul et al. (2021).

The Campo de Belchite county presents a critical demographic and economic situation compared to the Aragon regional average. This is explained due to the great gap existing in Aragon between the rural and urban realities. The remaining columns show the average results of the "counterfactual" estimated using the SCM for each model. As can be observed, this estimator obtains mean values of the variables much closer than the average of Aragon for the pre-intervention period, evidencing that the model is capable of realistically capturing the rural counties.

4. Results

This section presents the results obtained in the analysis of the impact of wind energy on the demography, economy and labour market in the Campo de Belchite county, using the methodology explained in the previous section. Results are presented as follows: First, a look at impacts on demographic, economic, and labour variables, such as population, gross value-added per capita, and employment. We then test our results by using the *placebo studies* and the Wilcoxon test, which are proposed as a way of analysing the robustness of both the methodology and the results.

Regarding the population effects of the installation of wind farms in the Campo de Belchite county, we use the logarithm of the population as a dependent variable. The remaining variables are used as economic, demographic, and geographical characteristics, which are suitable for representing the area under study in a synthetic way.

The results of the contribution of each county from the control group to the synthetic control group is shown in Table 2.

Results on population are shown in Fig. 2. The trend in both the region and the synthetic indicator is decreasing over time. Thus, investment in wind energy has not reversed this trend. In fact, when we compare the region with the synthetic control group, we can see that the trend in the Campo de Belchite county is slightly lower than its synthetic indicator, and this convergence has been aggravated in the years when the wind farms were installed. Specifically, on average, according to our results, there would be 2.58% more population in the region than at present. This leads us to conclude that the demographic effect of wind energy has been non-existent and, if they existed, would even be negative for some years. In other words, the development of these infrastructures did not contribute to curb the trend towards depopulation of these territories. The low participation of this sector in the total activity, its capital-intensive nature, and the inability to attract other related activities, linked to the development of the productive chain capable of attracting employment, prevented the activity from acting as a population driver for the area in the medium and long term. Furthermore, the decline in immigration suffered in the years of the economic crisis seems even more unstoppable in the area under study, with no evidence of a capacity to retain this population by substituting activities.

We now study the potential impacts of some important economic variables, such as the evolution of the Gross Value-Added (VA) per capita, as an indicator of the evolution of the regional economic structure.

The results show that the installation of wind farms has had two effects over time on the Gross Value-Added per capita. At the beginning of the period, in the stage of economic expansion, the value added per capita of Campo de Belchite was growing, but lower than that experienced by the synthetic control group. This fact again shows an inability of the installations to contribute to an outstanding growth in VA per capita in the short term (see Fig. 3).

However, in the long term, the economic impact has been greater than that experienced by the synthetic economy, reflecting the fact that the activity previously generated in the region acts as a strength for the regional economic structure, in comparison with the synthetic control group. Therefore, we could remark that there was a certain positive contribution in the long term, with all the necessary precautions, linked to the initial mobilisation of economic activity, which would prepare the region to better support crisis situations, possibly favoured by a potential increase in public and private resources linked to land rental processes, and associated taxes. Per capita income grew more than in the control group, without being reflected as a consequence of a greater diversification of economic activity. This growth has tended to slow down in recent years, showing a certain depletion of the impact.

The impact of wind energy on employment in the county is analysed below.[3]

First, it can be seen that investment in wind energy has not significantly reversed the downward trend in terms of job creation. As can be seen in Fig. 4, the trajectory of the Campo de Belchite county and the synthetic control group is very similar in both the pre- and post-intervention periods. That is, no impact is observed in 2006, nor in subsequent years associated with the installation of renewable energies. We can conclude that wind energy did not have any impact on employment in our study county. Focusing on the gap between the Campo de Belchite county and the synthetic control group (Fig. 4), it can be seen that in the year of the intervention (2006), there was a little convergence, probably due to the creation of jobs associated with the construction of the wind farms. However, this generation of employment was transitory.

Finally, one of the most common ways to evaluate the robustness of the methodology, and therefore our results, is through "in-space placebo studies". By this technique, we can test whether the methodology set out on the synthetic control method is really capable of representing the characteristics of the region under study. For this purpose, these tests propose to evaluate the intervention for the entire donor pool (where the event in question has not really happened), and a priori no effect should appear if, in fact, our synthetic control group is working correctly.

We analyze the same variables as in the Campo de Belchite county (population, VA per capita, and employment). Fig. 5 displays the results of the placebo test. The gray lines represent the gaps between the real and synthetic estimation of each variable for each of the remaining 30 counties. The black line represents the case of Campo de Belchite county.

In general, a gap around 0 is observed in the pre-intervention period for each case, demonstrating the suitability of the SCM. For the particular case of population and employment, the conclusions are similar, since for both cases, the gap continues to be around 0 both for the Campo de Belchite region and for the rest of the donor pool. However, in the case of value-added per capita, we observe that only two counties obtain

[3] The synthetic control method is estimated from the year 2002 onwards, in order to obtain the most realistic estimate possible for the period prior to the intervention. This is due to the large loss of jobs between years 2000 and 2001 in the industrial sector, what reveals that these jobs work in the region but do not have to live there (IAEST, 2000–2001). Note that the "counterfactual" is made up of counties similar to the previous models (see previous Table 2).

Table 1
Pre-intervention characteristics, 2006.

			Population	Value-Added per capita	Total Employment
	Campo de Belchite (1)	Aragon (2)	"Synthetic" Campo de Belchite (3)	"Synthetic" Campo de Belchite (4)	"Synthetic" Campo de Belchite (5)
Value-Added per capita	12.27	14.37	8.34	12.18	7.55
Gross Value-Added	66,162.42	714,795.3	47,088.93	99,176.58	36,412.7
Building Licences	11.71	136.99	26.76	34.12	28.94
Schools	0.00074	0.00074	0.00078	0.00074	0.00072
Urbanized land	0.0016	0.0087	0.0019	0.0045	0.0015
Population_log	8.605	10	8.605	8.79	8.44
Foreign Population	69.66	1549.4	127.19	158.4	132.14
Stability Rate	0.113	0.114	0.12	0.116	0.114
Ageing Index	347.6	168.63	292.63	240.71	264.4
Unemployment rate	0.0388	0.042	0.034	0.038	0.035
Temperature	14.1	12.82	10.55	11.41	9.62
Average Age	52.02	45.58	50.84	48.78	49.94
Total Employment	1753.14	19,320.61	1697.57	2285.75	1512
Population density	5.26	23.76	4.3	6.69	3.61

Table 2
SCM estimation of W-weights for each model.

County	Population	Value-Added per capita	Total Employment
La Jacetania	0.000	0.000	0.000
Alto Gállego	0.000	0.000	0.000
Sobrarbe	0.000	0.057	0.000
La Ribagorza	0.000	0.000	0.000
Cinco Villas	0.000	0.000	0.000
Hoya de Huesca	0.000	0.000	0.000
Somontano de Barbastro	0.000	0.000	0.000
Cinca Medio	0.000	0.000	0.000
La Litera	0.000	0.000	0.000
Los Monegros	0.000	0.000	0.000
Bajo Cinca	0.000	0.000	0.000
Tarazona y el Moncayo	0.000	0.000	0.000
Aranda	0.000	0.000	0.000
Ribera Alta del Ebro	0.000	0.000	0.000
Central	0.000	0.000	0.000
Ribera Baja del Ebro	0.000	0.000	0.000
Bajo Aragón-Caspe	0.000	0.114	0.000
Comunidad de Calatayud	0.000	0.000	0.000
Campo de Cariñena	0.000	0.000	0.000
Bajo Martin	0.000	0.000	0.000
Campo de Daroca	0.321	0.166	0.093
Jiloca	0.000	0.000	0.000
Cuencas Mineras	0.000	0.000	0.000
Andorra-Sierra de Arcos	0.000	0.160	0.000
Bajo Aragón	0.000	0.000	0.000
Comunidad de Teruel	0.000	0.000	0.000
Maestrazgo	0.000	0.000	0.282
Sierra de Albarracin	0.679	0.504	0.624
Gudar-Javalambre	0.000	0.000	0.000
Matarraña	0.000	0.000	0.000

Note that by varying the period of minimization (depending on the variable under study), the synthetic control group varies. However, for the 3 cases always more than 66% of the counterfactual for the 3 variables is formed by the region Campo de Daroca and Sierra de Albarracin.

a higher negative result at the beginning of the post-intervention period and only one higher at the end of this period, demonstrating the robustness of our results.

In the following figure (Fig. 6), we address the analysis of inferences known as "in-time placebos". The underlying logic of this test involves that the synthetic control method is re-estimated for another year in which there was no intervention. Confidence in the validity of the results is dissipated if the synthetic control method estimates a larger effect when the intervention did not occur (Abadie et al., 2010; Heckman and Hoztm, 1989).

Specifically, for our case, we performed the same analysis as above, but the year of intervention was 2003, 3 years before the installation of renewable energies. The periods before and after the intervention are very similar for population and employment. For the case of value-added per capita, small differences are observed, but in any case are smaller than in Fig. 3. In addition, the "in-time placebos" validate again our results.

To conclude this section, we analyze statistically the significance of the differences between the series observed in the Campo de Belchite county and the series obtained by the synthetic control method, following the proposal of Larramona and Sanso-Navarro (2016) and Sanso-Navarro (2011), who use the "matched-pairsigned-rank test of Wilcoxon" (Wilcoxon, 1945). This non-parametric test is used to compare the differences between the available data before and after some experimental manipulation, under the null hypothesis that the average of the estimated differences is zero. In this paper, we compare differences in each time period after the intervention.

Results are displayed in Table 3. In the case of population and value-added per capita, the null hypothesis is rejected at 5% significance, showing that the differences between the region and the synthetic control group are, on average, different from zero, so the effects we have analysed appear to be significant (very low and negative for the case of the population). However, in the case of employment, the null hypothesis of equality of means is accepted, showing that there are no significant impacts related to wind energy.

5. Discussion

In this paper, we approach an evaluation of the impact of wind energy on the Campo de Belchite county, from a holistic perspective. We try to better understand the complexity of a remote rural area, in which conventional indicators are probably insufficient. Based on the fact that there was a strong expansion of this type of infrastructure during the first decade of the 2000s, the short- and long-term effects have been estimated from a regional perspective. This analysis is novel, from a methodological point of view and in the way of approaching this type of evaluation.

The demographic results show that the installation of wind energy has had a negligible, and even negative effect in some years, on the population of the region, i.e. there is a certain indication that in the absence of this type of investment, the population would be larger than it is today. The possible reason, closely linked to the resulting employment, is that investment in wind energy detracts from other types of investment, which could perhaps generate more income and territorial consolidation, such as tourism or agriculture. In sum, the evidence does not support the notion that implantation of wind farms has helped to alleviate the strong phenomenon of depopulation in these areas.

The geographical location of the Campo de Belchite county may

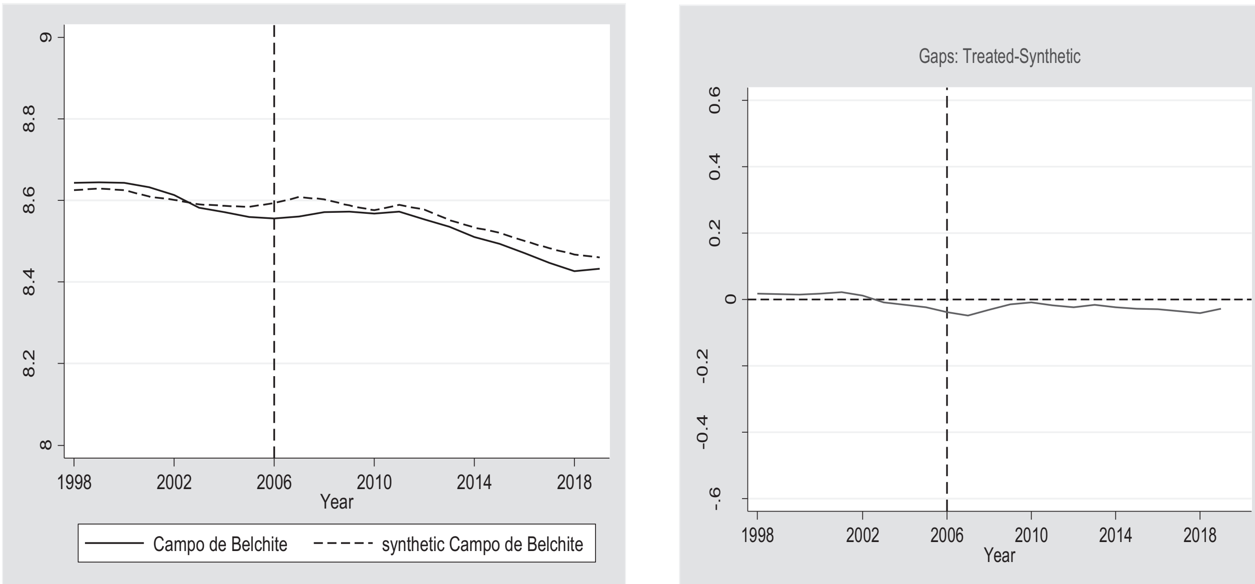

Fig. 2. Evolution of population in the Campo de Belchite county and its synthetic indicator.

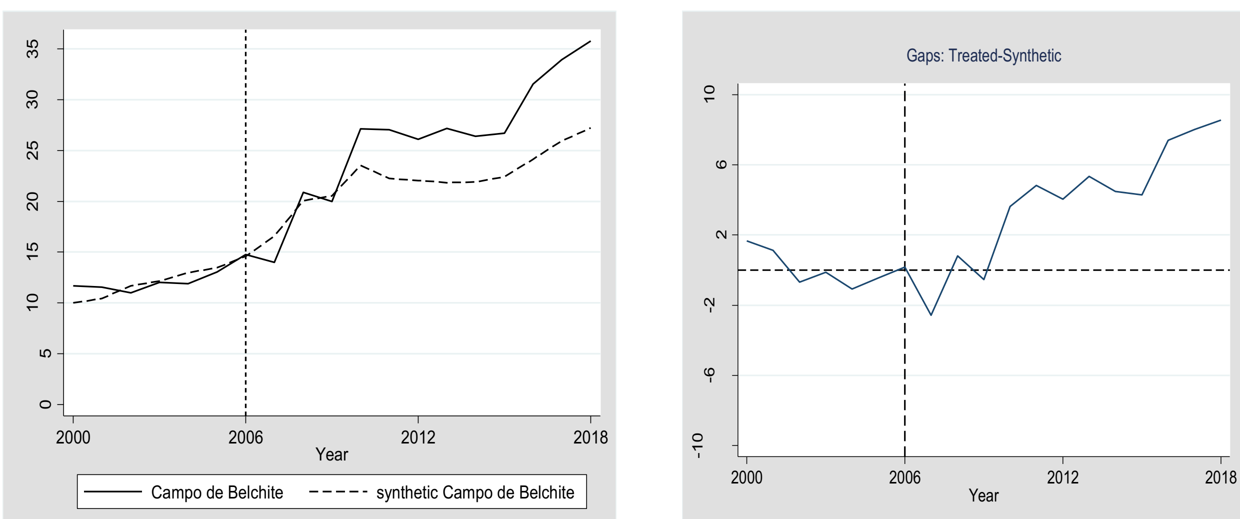

Fig. 3. Evolution of Value-Added per capita in the Campo de Belchite county and its synthetic indicator.

explain why these effects on the territory are so limited. Its proximity to the Aragonese capital means that the absorption effects of the city of Zaragoza outweigh the spillovers that its proximity could bring.

However, in economic terms, the long-term effect has been positive, increasing the per capita wealth of the territory, despite the negative effects on it in the short term; in other words, the economic effects are positive but not immediate. When we look at the sectoral composition of Gross Value-Added, we see that the process of tertiarisation of the regional economy has been more pronounced over the last decade than in the rest of the regions that compose the synthetic control group. However, these effects tend to diminish over time, suggesting the absence of a real process of structural and technological change in the territory, and the generation of endogenous capabilities to attract new productive investments beyond the initial stages.

Finally, the effects on the regional labour market suggest that the jobs created, linked to wind energy, are of a temporary nature, related to wind farm construction and first-operation processes, but with no significant positive effect in the long term.

The case study shows that renewables, as with conventional energy, is a capital-intensive economic activity. Our findings are in line with the conclusion of the OECD Report (2012), which states that energy generation is a highly capital-intensive activity, so direct employment and the associated multiplier are very low. It should be noted that the greatest source of direct job creation is concentrated in the installation and construction stages of the projects, which does not necessarily imply a qualitative structural change such as that required by many of the peripheral and declining rural areas. This dynamic is clearly shown in our study, where the various indicators confirm the inevitable demographic decline as a key factor that reduces human, social, and relational capital, and that the implementation of this type of activity has not been able to reverse.

6. Conclusion and policy implications

The development of renewables and their growing share in the energy mix is currently a strategic line of action for European countries as they move towards sustainable and low-carbon economies. The generation of energy through renewable sources has clear positive effects in

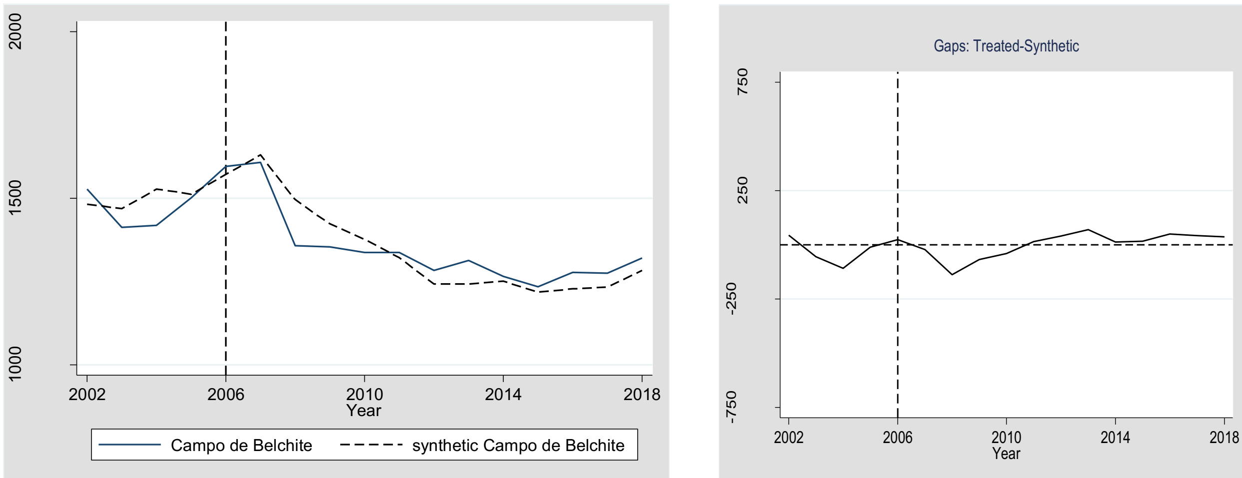

Fig. 4. Evolution of total employment in the Campo de Belchite county and its synthetic indicator.

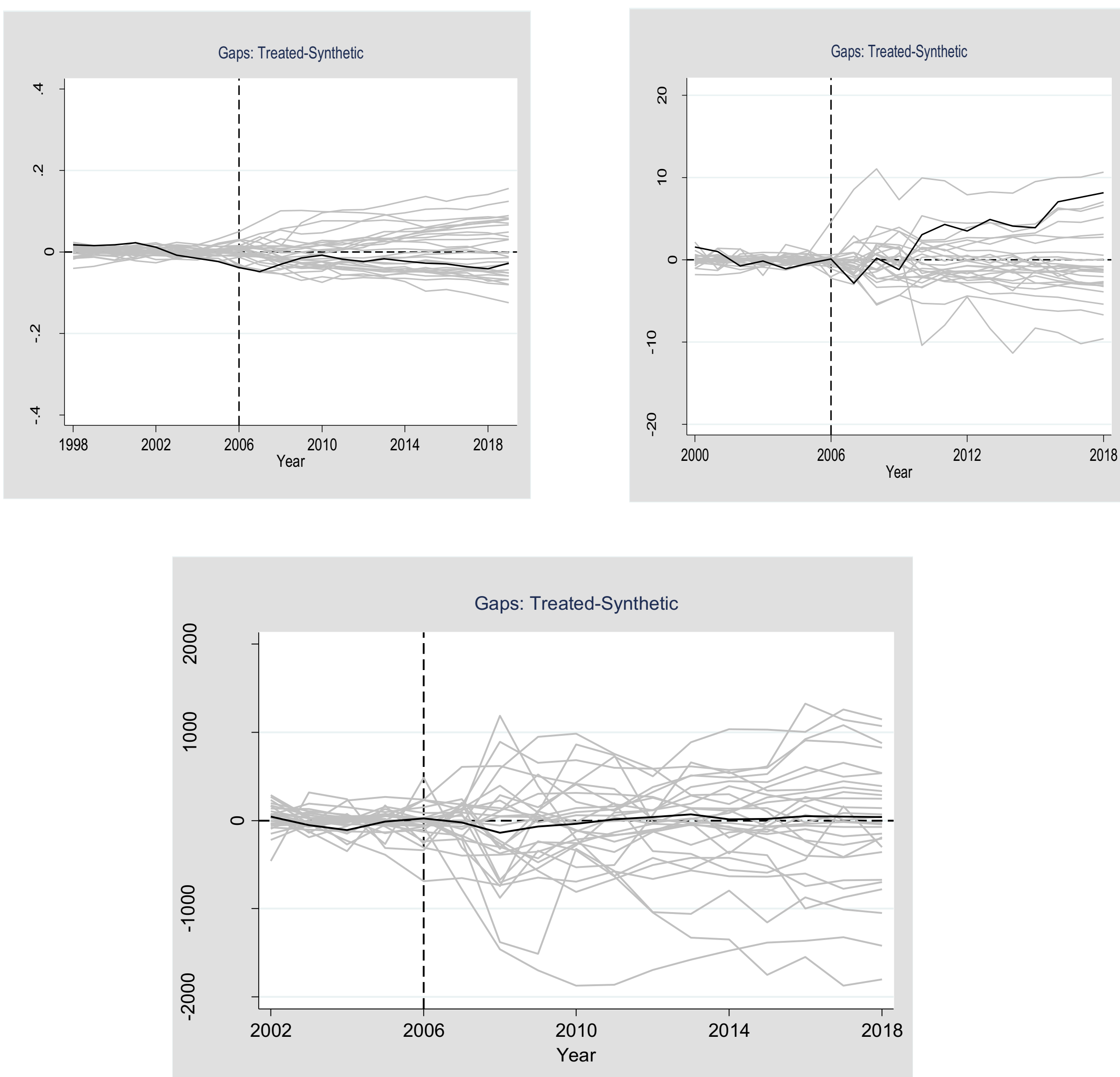

Fig. 5. "In-Space placebos" for the Aragón counties.

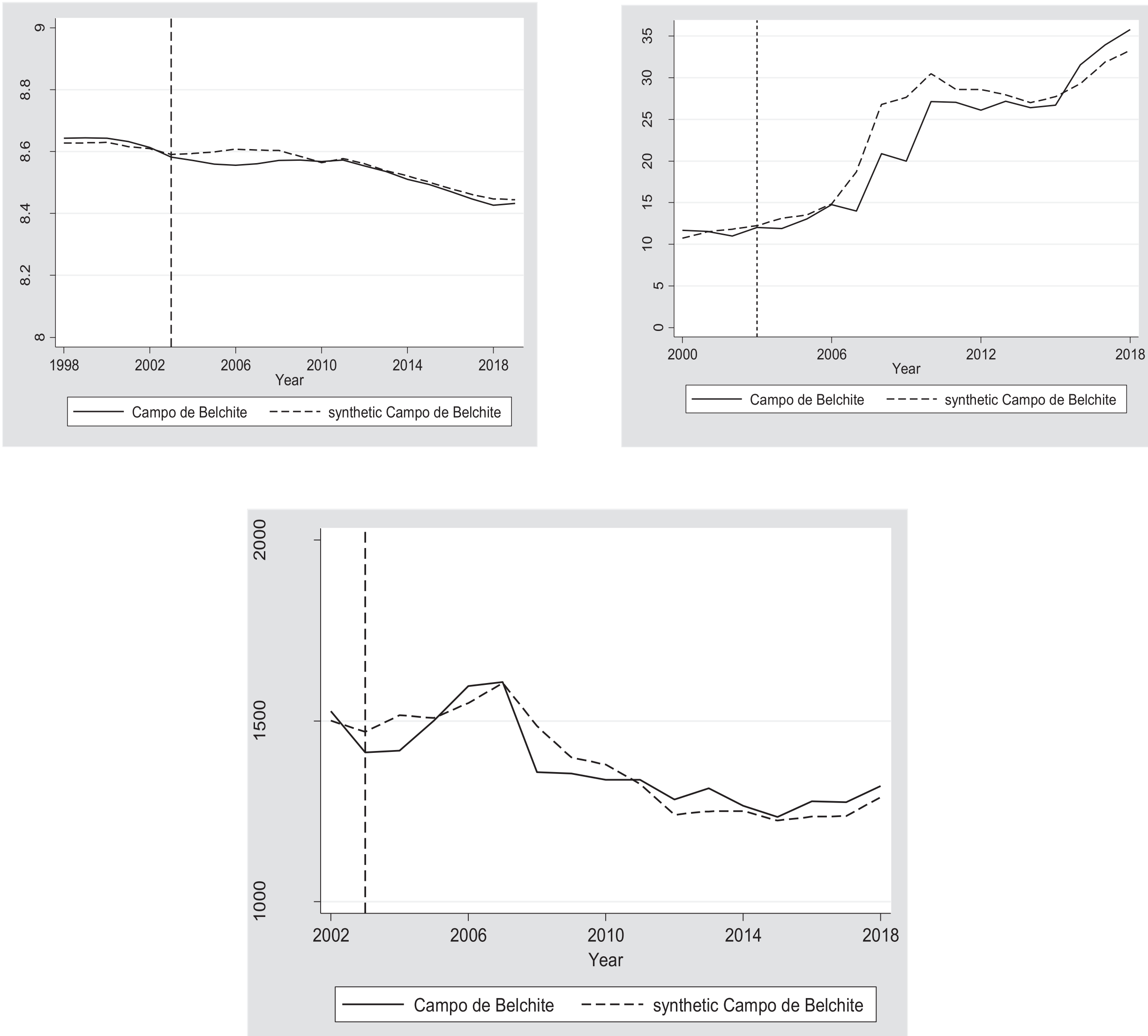

Fig. 6. "In-Time Placebos" for the Campo de Belchite county.

Table 3
Wilcoxon Matched-Pair Signed-Rank Test.

	Number of observations						
	Positive	Negative	Total	W^{+}	W^{-}	Test statistic	*p*-value
Population	0	14	14	0	105	21	0.001
Value-Added pc	11	2	13	85	6	17	0.0058
Employment	9	4	13	56	35	17	0.4631

environmental terms, economic terms as well as inducing a more efficient and cleaner mode of production.

The development of renewable technologies has been conceived by all levels of government, national, regional, and European, as a key strategy for mobilising investment in mature economies that lack dynamic projects. Thus, in the rural world, and especially in territories affected by energy reconversion, this could represent a powerful stimulus for their modernisation, boosting structural change towards more sustainable and participatory economies.

However, this potential cannot be taken for granted (OECD, 2012), and must be enhanced by public authorities facilitating synergies with different actors and communities, achieving greater involvement of these, increasing local acceptance, and developing the specific comparative advantages that may exist in these rural areas.

Thus, an important characteristic of the activity analysed, also observed in our study area, is that the energy sector represents a very small part of the total value-added and employment, and therefore has limited capacity to effectively transform territorial dynamics. In this line, our insights highlight the need for policy-makers to reinforce their participation and direct and indirect impacts, focusing on the need to attract new elements in the production chain, perhaps with energy prices that recognise the costs of transport and appreciate the proximity of where it is produced, or through progress in new R + D + I activities (especially in the latter, innovation), linked to the development of these energies which, by their nature, can benefit from the potential and values of the rural environment. To that end, promoting the involvement of a variety of public and private agents, social groups, and interests related to renewables, in national and international innovation and development programmes could act as the driving force behind initiatives with a strong social base, and serve as a forum for discussion, transparency and good governance in local communities.

As a concluding remark, our study suggests that the compatibility of socio-economic, demographic, and economic objectives associated with renewable energy development cannot be taken for granted per se and appoints out the need to reconsider its conceptualization, regional planning, and management, with a greater focus on the territory.

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Appendix A. Supplementary data

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