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Socioeconomic impact of wind energy on peripheral regions

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A B S T R A C T

The socioeconomic benefits from the development of wind power could go beyond environmental issues or the diversification of the energy mix. There is an increasing interest in quantifying the impact on regional economies of such deployment, especially in those peripheral regions with low growth rates and traditional declined sectors. However, many studies in this field are meta-analyses or they do not take into account the different dynamics between temporal and permanent activities in the sector as well as the regional singularities.

The main aim of this paper is to analyse the economic impact of wind energy, in terms of contribution to the GDP and job creation, applying as a case study the Spanish peripheral region of Galicia. This quantification is addressed from a regional and sectoral perspective. The methodology is based on the analysis of the value chains regarding the design of the investment breakdown between temporal and permanent activities, and the input–output approach in order to assess the economic impact. In addition, the regional symmetric matrices are updated by means of a variation of the RAS technique which avoids the fixed technical coefficients related to the traditional input–output models.

Empirical evidences underline the remarkable economic impact on the regional GDP and, to a lesser extent, on the employment. Although wind sector is capital intensive, employment increases in large amounts in industrial subsectors and knowledge intensive activities such as R&D. Hence, it might be an industrial alternative in peripheral regions if legislative instability is removed and promotion polices foster the regional value chain.

Contents

1. Introduction

Environmental issues and the diversification of the energy mix have been traditional main goals in policy agendas concerning the promotion of renewable energies. However, the consolidation of technological and economic mature alternatives to conventional energy sources could trigger remarkable economic benefits, such as the diversification of the industrial structures or job creation. This phenomenon points out the necessity of quantifying the economic impact as well as to assess their potentialities and the outcomes of policies. This analysis might be even more essential in peripheral regions which are characterised by institutional

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thinness, slow economic growth and a low level of innovative performance [1,2].

Wind energy is the best exponent of this consolidation and it has reached a high degree of diffusion and technological development. Nevertheless, the economic analyses of this renewable energy undergo some disadvantages concerning the abundance of meta-analyses and metrics based on MW ratios which do not consider regional specialisations [3,4]. There is also an analitycal necessity to contemplate the differences between temporal and permanent activities in wind power [5,6].

The main goal of this paper is to analyse the economic impact, in terms of contribution to the GDP and employment, applying as a case study the Spanish peripheral region of Galicia. This region was one of the leaders in Spain regarding installed capacity, but with a low level of industrial capacity. This quantification is performed both at the regional and sectoral level, considering the productive singularities and dynamics. The methodology is based on the analysis of the wind energy value chains regarding the examination of the cost and investment breakdowns between temporal and permanent activities and the input–output approach concerning the measurement of the economic impact. Furthermore, the paper avoids the drawback in the input–output approach related to the fixed technical coefficients [5,6]. It solves this weakness by updating the Galician simmetric matrices by means of a variation of the RAS technique which is a biproportional procedure of matrix adjustment. Hence, this more accurate methodology represents a step forward in the economic analysis of wind energy because it takes into account the different dynamics in temporal and permanent activities, as well as it solves the main disadvantages of input–output models.

The paper is structured in four sections. The first section presents a brief characterisation of the Galician peripheral wind sector, focusing on the main features related to the installed capacity evolution and the institutional context. The second section describes the methodology framework regarding the Leontief Quantity Model, the cost structure and the investment breakdown between temporal and permanent activities. Likewise, it explains briefly the matrix updating technique. The next section shows the main results linked to the quantification of the output multipliers, the sectoral contritubion to the GDP and the job creation. Finally, the conclusions summarise the most significant results and empirical evidences of this research.

2. Main features of the Galician peripheral wind sector

The deployment of wind energy began around the mid-90s, when some utilities implemented large scale projects in order to take advantage of the abundant resources in Galicia. Traditionally, Galicia stands out as one of the main Spanish region in terms of installed capacity. However, its development concerning industrial capacity as well as innovation and technological performance has not been remarkable [7] in comparison with other Spanish regions, such as Navarre.

The power of grant authorisations for wind farms and the spatial planning in Spain corresponds to the Autonomous Communities (equivalent to the Spanish regions). Likewise, public tenderings are based on the multicriteria bidding procedure which takes into account some regional economic benefits (e.g. job creation or industrial capacity) related to the development of this renewable energy [8].

Fig. 1 shows the evolution of the installed capacity in the period 2000–2013. In this sense, there are two different trends, identifying the change in 2007. The first one was characterised by a continuous growth in the installed capacity, which reached 3000 MW in 2007, departing from around 600 MW in 2000. The average annual cumulative growth was 25.4% between 2000 and 2007. However, this evolution was stopped by the legal instability since 2008, because that regional tendering was appealed and the stagnation of the new one (2010). In addition, other factors such as the start of the current economic crisis and the several changes in the remuneration scheme since 2010 make worse the situation. Since then, there is a stagnation with only 300 MW installed from 2007, with an average annual cumulative growth of 1.6%. Wind energy is a capital intensive sector and, therefore, financial and planning uncertainties are crucial. Hence, the impact on the sector of the cutbacks in the remuneration model is not trivial, especially, when all the turbines installed before 2005 do not receive any kind of subsidies and the new ones undergo a significant cutback with retroactive effects. In addition, wind farm owners have to pay a regional tax, based on the number of wind turbines installed, and a national tax estimated in the 7% of the value of electricity production.

3. Analytical methodology

The empirical methodology is based on the input–output (IO hereinafter) approach and the analysis of the wind energy value chain [10]. The economic impact study should keep in mind the regional special features, as well as the distinctive characteristics of value chains [6]. The analytical methodology is described in the next subsections, focusing on the specification of the Leontief Quantity Model, which constitutes the foundation for later quantifications. It also deals with the process of gathering and organising data; and finally the explanation of the updating technique applied in order to obtain more accurate results.

3.1. Economic quantification methodology

The economic quantification stands out as one of the main instruments in order to analyse the socioeconomic importance and the potentialities of sectors, specific variables or exogenous shocks, among others. Then, there are hardly any doubts about its relevance for policy design. For this purpose, the Leontief Quantity Model (also called demand pull) is applied because it enables to quantify the result of a stimulus or change in the final demand $\Delta y = (\Delta y_i)$; triggered by the installation of new wind farms and the permanent activities developed within the daily activity.

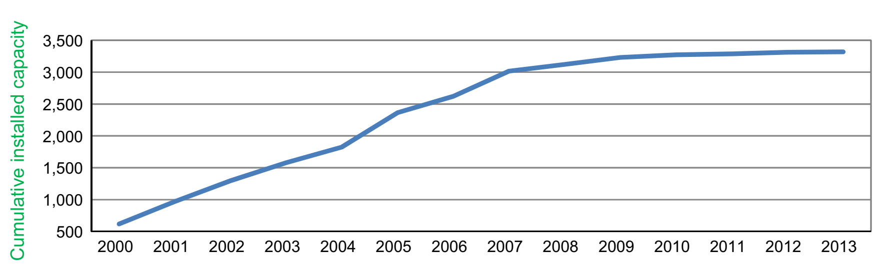

Fig. 1. Evolution of the wind energy cumulative installed capacity in Galicia (MW, 2000–2013) INEGA [9].

The foundations of the Leontief Quantity Model are based on Eq. (1) [11,12]

$$x=(I-A)^{-1}y=Ly, \tag{1}$$

where x is the output vector with n rows depending on the number of sectors; $(I-A)^{-1}$ or alternatively (L) represents the Leontief inverse or the total requirements $n\times n$ matrix; and y is the column final demand vector with n rows.

Eq. (2) gives more details

$$(I-A)=\begin{pmatrix}(1-a_{11}) & -a_{12} & \cdots & -a_{1n}\\ a_{21} & (1-a_{22}) & \cdots & -a_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ -a_{n1} & -a_{n2} & \cdots & (1-a_{nn})\end{pmatrix}\in M_{nxn}(\mathfrak{R}), \tag{2}$$

where $a_{ij}=z_{ij}/x_j$ is a technical coefficient which represents the demand of inputs from sector j produced by sector i per unit of output of sector j. Hence, this matrix embodies the inter-sectoral linkages and, therefore, the technological interrelations. It is calculated from the symmetric matrix, as well as the supply and use tables from the IO framework. These matrices are usually provided by the national/regional statistic offices and they constitute one of the basis for updating productive structures and general IO analysis. The supply table shows the provisions of goods and services by type of product and industry within an economy over a period of time. On the contrary, the use table depicts the consumption of goods and services by product, as well as by industry within an economy over a period of time. The symmetric matrix, the conversion of the two aforementioned tables, represents the sectoral productions by rows and the sectoral consumptions by columns. However, a full explanation of the input–output tables is not the main aim of this paper; for further information (see Eurostat [12]).

Then, if it is known an increase in the final demand of one or several sectors in the economy, it is possible to quantify the output increase in each sector as well as the total one.

There are two different effects present on the output. Firstly, the direct effect triggered by the stimulus in the final demand and equal to it. This stimulus undergoes only to specific subsectors. Secondly, the other sectors have to increase their production in order to meet the intermediate demand, that is, inputs for the production of good and services which underwent the stimulus in the final demand. At the same time, these last subsectors also need inputs from the rest of the economy and, therefore, increase the whole output in another amount. Then, there are several rounds like this in the economy. This last successive effect is the indirect effect on the output. This total effect could be quantified by means of the output multiplier $(m(o_j))$, which is the sum of the elements of the vector Δx. Eq. (3) shows that in mathematical terms

$$m(o_j)=i^T\Delta x \tag{3}$$

Given a certain increase in the output, the contribution of the wind sector to the regional economy is calculated by means of quantifying the proportion of this output which is final demand and then, part of the GDP. A demand side way to calculate the GDP is the following: $GDP=C+I+G+(X-M)$; where C is the final consumption by households, I represents investment, G is government expenditures and the final addend is net exports. It is done through analysing that proportion in the annual accounts elaborated by the Galician Statistic Institute (IGE). Hence, it is based on the IO general principle of constant economies of scale.

Concerning the employment quantification, this issue is addressed from the output results. In this sense, the vector of employment is showed in Eq. (4)

$$e^T=\begin{pmatrix}e_1/x_1^0 & \cdots & e_n/x_n^0\end{pmatrix}\in M_{1xn}(\mathfrak{R}), \tag{4}$$

where e_i is the full time equivalent employment in the sector i, and x_i^0 is the output of sector i in the base year. This vector is available per each year in the period 2000–2010, because the data are provided by the IGE, in the IO tables, as well as the annual regional accounts.

Then, Eq. (5) quantifies the direct employment created by the stimulus in the final demand, as well as the indirect employment created by the intermediated consumption linkages

$$\varepsilon=\hat{e}(1-A)^{-1}y=\hat{e}Ly, \tag{5}$$

Here, ε is a vector with n rows which represents the employment created given a stimulus in the final demand and $e^{\wedge}$ is a diagonal matrix whose non zero components are the values of the vector of employment coefficients. In addition, the calculation of the employment multiplier is through Eq. (6)

$$m(\varepsilon)=i^T\Delta\varepsilon \tag{6}$$

In the next sections, these tools enable to estimate the main economic impacts of wind energy on the regional economy. These outcomes make easier the sectoral diagnose and the policy design process.

3.2. Analytical framework and data

The analytical framework presents an essential particularity which makes easier an accurate and more sophisticate analysis. The sectoral activities are classified into two groups with different dynamics. The first kind of activities is related to the temporal activities, that is, the installation of wind farms. They include the design and manufacture of wind turbines, assembly and installation, civil works, electrical equipment, etc. These activities are characterised by their dependence on the installation of new capacity. Hence, their evolution also depends on different variables, such as the stability of the legislative framework (particularly, normative regarding public tenderings and remuneration schemes), business cycles and technological innovations, among others. On the contrary, permanent activities include the operation and maintenance (O&M) of a wind farm, in order to keep it in optimal and safety conditions, as well as the generation of electricity. These last activities are determined by the cumulative installed capacity and, to a lesser extent, by the meteorological conditions (electricity production). This analytical framework solves the essential problem of tailoring the temporal and permanent economic impacts of wind energy at regional level [5,6], increasing the analytical and descriptive capacity. Given that most seasonal activities depend on the economic cycle and the normative framework, the investment evolution does not show a stable trend and it presents a moderate volatile evolution. However, branches related to daily O&M follow a positive evolution trend, because these activities and electricity production depend on the cumulative installed capacity and the meteorological conditions.

Seven branches represent temporal activities, following the NACE-Rev1.1. The classification NACE-Rev1.1 is suitable for the current analytical purposes, due to the updating of domestic symmetric matrices is for the period 2000–2010. Given the existence of two IO frameworks (years 2005 and 2008), it was necessary to keep a same level of homogeneity for all the branches and over time. Thus, several initial branches from IO tables are merged. The final intermediate consumption matrices (X^d) are 51×51. The selection of branches is based on the wind energy sector value chain, interviews with the main stakeholders in Galicia (component manufacturers, consultancies, business associations, wind farms owners and electricity companies) and previous studies, such as Aixalá et al. [13] and Blanco and Rodrigues [3].

Table 1 shows these branches related mainly to component manufacturing activities, construction, consulting and financial sector. It also provides the main components in each branch, as well as the percentage of the initial investment per MW undertaken in Galicia. This last information is vital in order to quantify the real economic impact of the wind sector, because the other components are imported and, therefore, they do not stimulate the regional economy. Hence, it should be isolated the share of the suppliers which provide goods and services to the wind sector from Galicia. The issue of wind exports from Galicia is not addressed because several interviewees asserted that during the sectoral boom, there were limited and the Galician facilities were concentrated on meeting the demand from inside. Moreover, some authors have pointed out that exports are globally reduced in comparison with sectoral foreign direct investment [14,15]. Aixalá et al. [13] isolate the regional suppliers for the Spanish region of Aragon by means of the information of local content requirements in the agreements among wind farms developers and the regional government in public tenderings. However, at least in Galicia, there is a general breach of contracts [16] and it would not be a good option to follow this information.

The quantification of the final demand vector (Δy_i) is calculated from the annual data of installed capacity published by the Galician Energy Institute (*INEGA*) and the average cost of the investment by megawatt in Spain in 2006 [17]. These values are reduced by the amount of the historical average VAT rate (16%) for the period of analysis. The same occurs with the costs of operation and maintenance activities. Likewise, this investment is shared between the branches based on the installation cost distribution of wind farms [18–20]. Afterwards, we allocate the aforementioned investment percentage which means the share of the total investment implemented by Galician stakeholders. This allocation is based on quantitative and qualitative information gathered combining the mentioned interviews and census data from the Galician Wind Energy Association (*EGA*) and the Spanish Wind Energy Business Association [21]. In relation to the branch 65 (financial services), the Galician saving banks market shares in domestic private loans is selected as an allocation parameter [22] in 2000–2010. Galician saving banks had a more active role in the credit business to the industrial sector in comparison to the bank system [23]. The direct quantification of the percentage of loans of the Galician financial firms to the wind energy sector constitutes a complex task, due to the fact that it is usual the underwriting of syndicated loans with several financial firms and the confidentiality clauses. Hence, the resulting value of the final demand vector has a temporal multiplier impact on the regional economy.

The analysis of the permanent activities is accomplished by means of the selection of the branch 40 (production of electricity) and three branches which represent the impact of O&M activities. These three branches develop repairing tasks in the NACE-Rev1 but branch 33 is in charge of them in NACE-Rev2. Table 2 shows the aforementioned branches.

Data collected of electricity generation, published by INEGA, are used to quantify the impact of electricity production. Based on these data, the value of the electricity production is quantified by means of the price that the producers receive, thanks to the information offered by the Spanish National Commission of Energy (*CNE*). This value encompasses the price negotiated in the energy market (spot price) plus incentives and premiums. Until 2004, there was no direct negotiation in the energy market; therefore, the initial value came from the sale to the distributor. Since that, more than 90% of the production is commercialised in the energy market. The producers who choose the option of regulated price are residual. Nevertheless, this value does not still constitute a final demand vector; therefore, it is necessary to filter the data in order to obtain the final demand vector for the branch 40, disregarding the intermediate production.

The estimations of EWEA are useful to quantify the operation and maintenance costs. These estimations refer to the costs in relation to the kWh produced. EWEA estimated costs between 1.2 and 1.5 cents of € per kWh for wind farms in Spain, Denmark, United Kingdom and Germany in 2006. This study takes the average value. Likewise, the resultant value should be filtered, due to the fact that EWEA asserts that only 60% would be properly costs of maintenance and repair. As in the case of electricity production, screening the results to obtain the final demand vector and allocate the final value among the three branches in charge of

Table 1
Wind energy sector branches with temporal effects on the economy.

Branch codes	Concept	Main wind turbine components and tasks	Percentage of the investment per MW[a]
28	Manufacture of fabricated metal products, except machinery and equipment	Towers, cast components	15.00
29	Manufacture of machinery and equipment	Hydraulic systems, bearings, blade bearings, nacelles, blades	19.67
31	Manufacture of electrical equipment	Electric installation, gearboxes, generator, cables	17.44
45	Building	Civil works	8.00
65	Financial service activities, except insurance and pension funding	Financial services	0.54
52–72	Retail trade, with the exception of motor vehicles; computer activities and reparation of personal belongings and domestic instruments	Control and monitoring systems (SCADAs)	0.0
74–85	Health and veterinary activities. Social services and other business activities	Environmental and topography reports	1.20

Own elaboration adapted from Blanco and Rodriguez [3], Aixalá et al. [13], Hau [18], EWEA [17,19,20], Vasallo [23], and Varela et al. [10].

[a] These percentages of investment are filtered in order to quantify the production undertaken in Galicia.

Table 2
Wind energy sector branches with permanent effects on the economy.

Branch codes	Elements
40	Electricity, gas, steam and air conditioning supply
28	Reparation and maintenance of fabricated metal products, except machinery and equipment
29	Reparation and maintenance of machinery and equipment
31	Reparation and maintenance of electrical equipment

Own elaboration and based on Varela et al. [10].

operation and maintenance activities represents an essential task. This allocation is based on the weight of each branch in the final demand in the annual symmetric matrices.

Finally, there are two final demand vectors, one for activities related to the installation of wind farms and another for permanent activities. Following the process of the Leontief inverse, it is possible to quantify output multipliers, as well as the economic impact of the sector in terms of GDP and employment.

3.3. Updating matrix coefficients

The last two IO tables available for Galicia correspond to 2005 and 2008. Previously, the Galician Statistic Institute (IGE) published an incomplete IO framework in 1998 (methodology ESA-95), but due to diverse reasons, it is not recommended to use it. Apart from the differences of aggregation criterion and the effect of prices, these tables will serve as a base to carry out a matrix series of the productive structures from 2000 to 2010, because of the existence of annual information of some macroeconomic variables. In this study, IO tables are not deflated. Diverse authors [11,12] examine the disadvantages of deflation. They stand out mainly the need of a high level of sectoral breakdown and homogeneity by groups, due to the fact that all the elements of each row of the intermediate consumptions matrix should be deflated by the same index. In addition, the interindustrial prices can vary in a large extent among them. The effects of the level of prices will be mitigated in the technical coefficients matrix, because there will be an inflationary or deflationary effect on the numerator as well as on the denominator. A preferable alternative to the deflation is a biproportional method of adjustment, such as the RAS [11]. It seems reasonable to undertake the corresponding estimation in order to avoid focusing only on years 2005 and 2008, especially if there are enough elements to apply methods of matrix updating. In addition, a weakness related to the existence of static technical coefficients in IO models [5] is avoided.

If the production and value added growth rates and the total imports are known, such as in this case, it is possible to update the symmetric domestic table. The basic RAS is not suitable with this information, because the row sums of the intermediate consumptions matrix are unknown. Likewise, it is important to keep in mind that RAS is a biproportional technique of matrix adjustment that consists of multiplying successively the rows and the columns elements of a basic matrix by some parameter until accomplishing a convergent solution. This iterative procedure was proposed by Stone and Brown [24] and, over time, their foundations and extensions have considerably increased; (see for example Bacharach [25], Allen and Lecomber [26] and Szyrmer [27]).

In spite of the lack of the vector of intermediate demand, the basic RAS has been adapted. To implement the extension of the RAS, in accordance with the available information, it is necessary to act jointly on the intermediate consumption and final demand domestic matrices, because the margins of this combined matrix are known. In those cases in which IO tables in base years are available, it might be possible to carry out contrasts among the estimations and the real data. The evolution of the total components of the final demand is unknown, but if they are added in a single vector, their total could be quantified by difference between magnitudes. It is necessary to guarantee the accounting equilibrium in the IO framework.

Concerning the matrix combined, it is essential to include several sub-matrices. In particular, there are the domestic intermediate consumption matrix X^d and the intermediate import matrix X^m. Additionally, there are the domestic final demand matrix Y^d and the import final demand matrix Y^m.

Therefore, Eq. (7) shows analytically the combined matrix

$$(X \vdots Y) = \begin{pmatrix} X^d & Y^d \\ X^m & Y^m \end{pmatrix}. \tag{7}$$

In general, the matrix $(X \vdots Y) \in M_{2n \times (n+f)}(\mathfrak{R})$,where n is the number of industries and f is the number of components of the final demand.

If the aim is to update the matrix of domestic intermediate consumptions, it is recommended adding the import flows in a single row vector and the final demand in a vector column. Eq. (8) shows this process

$$(X \vdots Y)_{combined} = \begin{pmatrix} X^d & Y^d i \\ i^T X^m & i^T Y^m i \end{pmatrix} \in M_{(n+1)\times(n+1)}(\mathfrak{R}), \tag{8}$$

where i is a column matrix of ones and i^T is its transposed.

As the vector of imported intermediate consumptions is known, $i^T X^m$, and the total imports to final demand, $i^T Y^m i$; the extension of the RAS can be applied on the matrix (Eq. (9))

$$\left(X^d \vdots Y^d i\right). \tag{9}$$

4. Regional economic impact of wind energy

The main empirical results derived from the application of the IO analysis to the Galician wind energy sector are the output multipliers, the wind sector contribution to the regional GDP and the employment creation.

Given the matrix updating in order to quantify the annual economic structures, the next step is to calculate the output multipliers. These multipliers estimate the initial direct effect caused by the increase of the final demand as well as the indirect effect on the remaining economic sectors to be able to satisfy the demand of intermediate consumptions triggered by the initial stimulus. The quantification is valid both for temporal and permanent activities.

The multipliers quantification allows analysing the additional output increase which constitutes a magnitude that shows the relationship between the increase triggered by the final demand and the initial stimulus. It enables to quantify the total outcome per euro of final demand.

Table 3 shows the additional output increase triggered by the wind sector as a whole, as well as breaking down for temporal and permanent activities. As shown, the overall additional effect is stable throughout the period and very significantly because per each euro invested directly to final demand in the sector, there are between 0.46 and 0.54€ additional increase in the total output. Hence, wind sector activity is profitable for the economy in terms of production and intermediate consumption linkages. The size of the multiplier is due to the subsectors involved in the initial stimulus are strongly interconnected with the rest of the regional economy and, therefore, they demand intermediate goods and services in order to meet their own demand.

The output increase due to an investment in new farms is slightly smaller than the same effect triggered by permanent activities (O&M plus electricity production). In this sense, until 2005 the investments in temporal activities as well as its total output created represent the lion's share in the sector. In fact, the increase in the sectoral multiplier was due to the relative increase of the weight of permanent activities.

Fig. 2 shows the wind sector contribution in the regional economy. It includes direct plus indirect effects. The GDP data are in real terms on base 2005, corrected of seasonality and calendar effect. Likewise, the production to final demand of each subsector was deflated by means of the implicit deflator on base

Table 3
Estimation of the direct and indirect production triggered by the wind sector (thousands of euros, 2000–2010).

	Temporal activities			Permanent activities			Whole sector		
	Initial stimulus	Total	Additional effect (%)	Initial stimulus	Total	Additional effect (%)	Initial stimulus	Total	Additional effect (%)
2000	94.743	135.422	43	43.253	66.173	53	137.996	2015.94	46
2001	220.303	316.014	43	66.455	104.313	57	286.759	420.327	47
2002	203.514	295.259	45	101.548	152.831	51	305.062	448.091	47
2003	176.141	256.202	45	103.264	154.251	49	279.405	410.453	47
2004	153.183	224.481	47	139.011	209.413	51	292.195	433.894	48
2005	337.912	493.580	46	221.944	342.734	54	559.856	836.314	49
2006	161.088	236.520	47	229.583	360.360	57	390.618	596.880	53
2007	248441	365.476	47	205.776	316.937	54	454.217	682.413	50
2008	65.841	95.764	45	259.143	405.326	56	324.984	501.086	54
2009	67.698	98.815	46	245.700	373.584	52	313.398	472.398	51
2010	26.173	38.240	46	279.384	415.725	49	305.557	453.965	49

Own elaboration and based on Varela et al. [10].

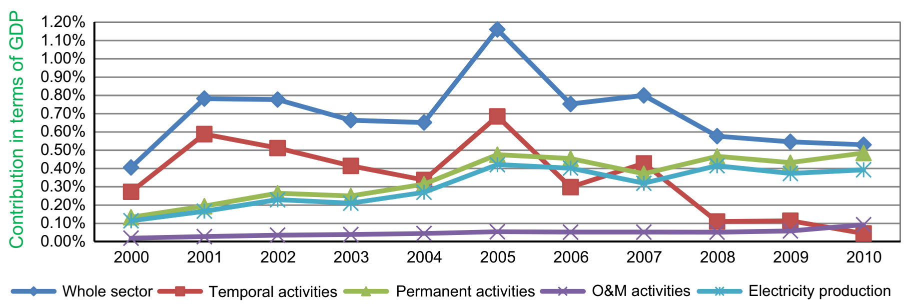

Fig. 2. Estimation of the wind energy sector in terms of the Galician GDP (2000–2010) Own elaboration and based on Varela et al. [10].

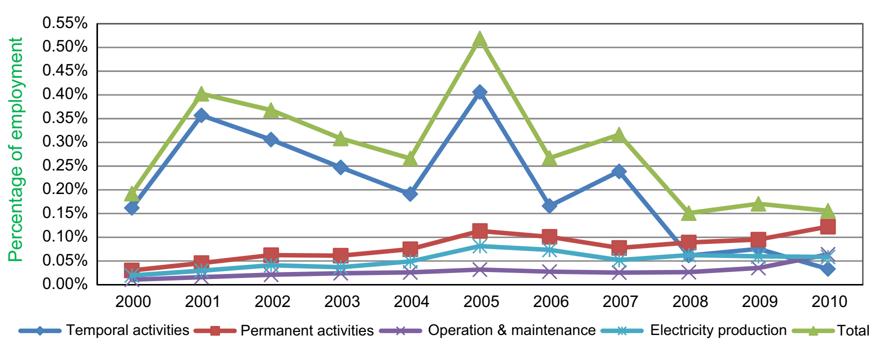

Fig. 3. Estimation of the wind energy employment in terms of the total regional employment (2000–2010) Own elaboration.

2005. This quantification is crucial in order to measure the size of the sector in relation to the whole economy. It also emphasises the importance of public policies which boost the sector, as well as its potentialities. Equally, it can check the impact of the economic cycle and normative changes on the sector. Likewise, the breakdown based on the value chain stands out the relative importance of each subsector.

The contribution of the wind sector in the Galician economy changes substantially over time. In 2005 reached the highest value (1.16% of the GDP) due to the installation of new wind farms (roughly 0.69%) and the electricity production (0.42%). That year constituted the moment with more new installed capacity, with 540 MW. However, it also reached lower figures, such as at the beginning and at the end of the decade (0.40 and 0.54%, respectively). The contribution to the economy was above 0.70% between 2001 and 2007.

It should be also pointed out the contribution of the installation of new wind farms to the GDP until 2007. It was always above 0.3%, therefore, it constitutes the main driver in the wind energy sector and an essential additional output increase in the economy. This evolution reflects the large sector peak, with installed capacity annual growth rates higher than 10% and even reaching 57% in 2001. Since 2007, there were two complete different sectorial legislations with opposite guidelines and the wind public tendering was appealed in 2008. Likewise, it should be highlighted the current changes in the remuneration regimen and the new context of economic crisis. The result was a crucial shutdown in the installation of new capacity, which blocked the sectoral development. The dependence on the installation of new capacity emphasises the harmful effects that the paralysis of public tenderings triggered in the Galician economy.

At the end of the decade permanent activities play a palliative role in contrast to the unfavourable evolution of the annual installed capacity, because their contribution to GDP has increased. This fact is mainly justified by the contribution of electricity production with the exception of meteorologically adverse years. The special regimen has preference in the energy market; therefore, it is not affected by fluctuations of the energy market.

Likewise, the contribution of operation and maintenance activities is insignificant (underneath 0.1% of the GDP). Consequently, it does not constitute an economic driver. Hence, there is no sufficient wind turbines stock in order to reach an important contribution to the economy. The permanent component of the sector has not still significant size to sustain a repair market.

In spite of the significant contribution to the regional GDP, job creation could constitute a more tangible way to approximate to the socioeconomic benefits of renewable energies. Its role is even more relevant in peripheral regions, where the lack of labour opportunities and new market niches are common. In this sense, Fig. 3 shows the evolution of the wind energy direct and indirect employment with regard to temporal and permanent activities (O&M plus electricity production), as well as the whole sector between 2000 and 2010. The employment figures are referred to the total regional employment.

One of the main sectoral characteristics regarding employment is the relative low level of labour intensity. If the sectoral GDP contribution represents 1.16% of the regional economy in its peak, and 0.40%, in its bottom, the direct and indirect wind employment could not overcome the cap of 0.52% of the regional employment (5.633 employees). Wind employment touched down in 2008 when the percentage was roughly 0.15% (1.765 employees). The estimations indicate that sectoral impact in terms of employment is less than a half of the GDP contribution. Moreover, temporal activities (installation of new installed capacity) represent the lion's share of the total employment until the slowdown of 2008. Hence, the results confirm the established assertion that operation and maintenance activities and electricity production are not labour intensive. One of the main consequences of that fact could be the unreliability of permanent activities in the event of a shortage of suitable places for new wind farms based on large development models. In this sense, if job creation figures on policy agendas, it would be necessary to foster repowering or green transitions, such as the deployment of small wind turbine technology related to the cattle industry; among others. Concerning the feasibility of repowering, Colmenar-Santos et al. [28] have undertaken an analysis in Spain regarding the market for repowering. Likewise, they have developed a comprehensive technical as well as economic simulation, without the feed-in-tariffs scheme, comparing new wind farms and repowered ones with a case study in Galicia. In this sense, in terms of market size in Spain, there is a market of 2.3 GW, with an approximate annual growth of 1 GW. In addition, repowering can be more profitable, especially, in the case that some facilities are reused and maintaining a minimum level of stability regarding legislative framework.

Despite this overall low labour intensity, analysing the job creation more in depth is essential because, beyond the general figures, there could be specific subsectors beneficiaries from the deployment of this renewable energy. Likewise, this detailed analysis enables to diagnose different benefits to the primary, industrial and service sectors, as well as unexpected job creations through examining the indirect employment. Then, even the general impact on the employment is limited, wind energy deployment could trigger, at the subsector level, crucial additional output increase and, therefore, an important relative boost in the job creation. Depending on the subsector, wind energy might represent an alternative to traditional sectors.

Concerning the estimation of the wind energy employment created by the stimulus in the final demand, Fig. 4 depicts the evolution for the seven branches analysed related to temporal, as well as permanent activities. First of all, it should emphasize the significant importance of the industrial related branches “manufacture of machinery and equipment” (29) and “manufacture of electrical equipment” (31). The weight of wind power employment in both branches evolves from the bottom reached after the slowdown in 2008 (around 3% of the total sectoral employment) and their peak in 2005 (slightly below 18%). This job creation depends on the installation of new wind farms and also, to a lesser extent due to a limited job intensity, on operation and maintenance activities. In addition, the branch “manufacture of fabricated metal products, except machinery and equipment” (28), has undergone an increase of wind power employment. It represented 6% of the total sectoral employment in 2005 and it was always above 1.6%. Then, it seems to conclude that the wind energy deployment has a significant impact on industrial employment and it could constitute a potential alternative to traditional industrial sectors in Galicia such as the naval one, especially, owing to the fact that both of them share partially the same subsectors. The cognitive proximity is confirmed by the fact that shipyards or naval auxiliary firms made several wind turbine components such as towers, nacelles or blades, among others.

The branch “Electricity, gas, steam and air conditioning supply” (40) underwent important benefits in terms of employment creation, when the installed capacity was growing annually at double digit. In this sense, wind power employment represented a stable portion of the sectoral occupation between 8.35% and 6.90% from 2005 until 2010. This subsector is not labour intensive; therefore, the approximately 160 employment full time equivalent working there in 2010, due to the direct stimulus and the indirect effects, indicate an essential relative contribution.

Whilst the building subsector (45) represents 8% of the total cost of the wind farm installation [17] and it is labour intensive, the importance of the relative job creation derived by the wind sector is symbolic. The annual average during the whole period reached 0.31% (slightly less than 500 employees). The main reason is due to the total sectoral employment, as well as the GDP contribution to the economy was unusually high during the housing bubble. Then, in a bubble context, the weight of the jobs related to the wind sector was underrated. The direct and indirect job in the branches “financial service activities, except insurance and pension funding” (65) and “health and veterinary activities. Social services and other business activities” (74–85AB) is usually below 0.40%.

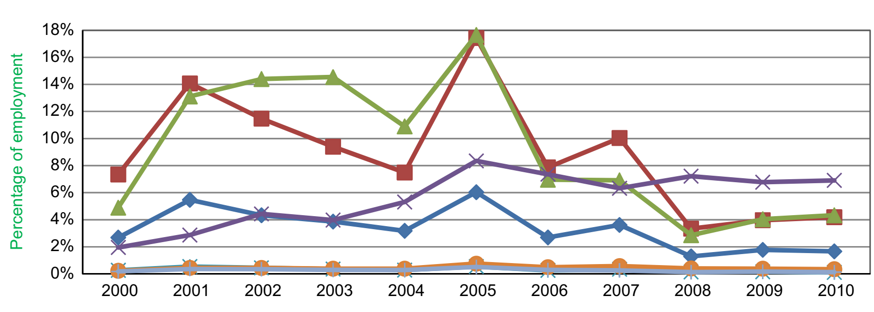

Fig. 4. Estimation of the wind energy employment in the branches affected directly by temporal and permanent activities (2000–2010) Own elaboration.

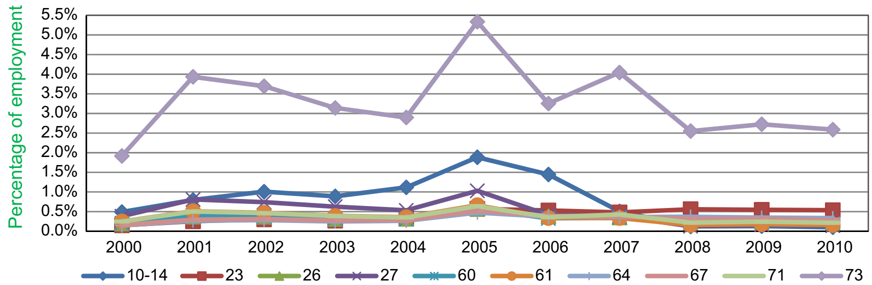

Fig. 5. Estimation of the wind energy employment in the main branches affected indirectly by temporal and permanent activities (2000–2010) Own elaboration.

Last, but not least, Fig. 5 shows other branches with a significant job creation, but these are not affected directly by the stimulus in the final demand derived either by the installation of wind farms, operation and maintenance or electricity production. The selection criterion of these branches is based on the choice of those branches with a relative employment creation above regional average throughout the analysed decade. Overall, there are ten braches with better evolution that the average.

The branch 73, which develops research and development tasks, is the main indirect beneficiary of the wind energy activity. In this sense, the indirect employment created reached the peak of 5.34% of the total regional employment in 2005 (33 employees). Moreover, it was always above 2% during the analysed period and it represents ten times the global impact in the regional economy. Then, the exploitation of the wind energy in the peripheral region of Galicia has been beneficial in the employment of engineers, scientists and other workers enroled in R&D activities. Despite the poor absolute employment figures (33 employees), this employment is created indirectly by means of intermediate consumption linkages, because in Galicia there is neither public technological centres nor private wind R&D facilities. Thus, if the regional wind sector develops R&D activities (e.g. undertaking the design of new wind turbine models, components, etc.), the impact would be higher. Anyway, this outcome is essential, especially in those regions with low R&D and innovative performance, because wind power could constitute an attraction for high skill labour and a focal point for technological activities. In addition, it could also represent a partial solution for demand side bottlenecks in some European peripheral regions, where university graduates in science related domains have a lack of job opportunities.

It should also be highlighted the contribution of the wind sector to "mining and quarrying" (10–14), as well as "metallurgy" (27). The former one is related to the exploitation of natural resources and its relevance is due to the stimulus to the building and industrial subsectors present in the wind value chain. Likewise, "metallurgy" provides inputs, mainly to the subsectors of "manufacture of fabricated metal products, except machinery and equipment" (28); and "manufacture of machinery and equipment" (29). These linkages within the intermediate consumption network explain their relevance in terms of job creation.

Others subsectors with important job creations are "manufacture of coke, refined petroleum and nuclear waste treatment" (23); "manufacture of other non-metallic mineral products" (26); "land transport" (60); "water transport" (61); "posts and courier activities" (64); "activities auxiliary to financial intermediation" (67); and "renting of machinery and equipment without operator, of personal effects and household goods" (71).

5. Conclusions

Wind energy stands out as one of the most mature renewable energies, in terms of technological development and diffusion. The socioeconomic and environmental benefits, which arise from its emergence, have triggered an increasing interest of practitioners. Concerning the socioeconomic field, the quantification of the impact of renewable energies in the production and employment represents a main goal in order to assess the revitalizing role of wind power, especially, in contexts with a high unemployment rate and macroeconomic volatility. Then, this paper is focused on the aforementioned analysis in peripheral regions because the potential outcome could be remarkable to diversify the economy towards new sectors and technological paths. In addition, it might be a useful tool to undertake an assessment of promotion policies and their effectiveness.

This paper develops a new and more accurate methodology regarding the analysis of the GDP contribution of wind power, as well as its job creation. In this sense, the methodology avoids the use of coefficients based on the installed capacity, and it separates the dynamics of permanent and temporal activities related to wind energy. Likewise, the paper overcomes another key disadvantage of input–output model linked to the fixed technical coefficients. All of these enhancements improve the economic estimations of the importance of wind sector.

The results enlighten the economic impact of wind energy on a typical peripheral region. Despite the lack of international competitive industrial agglomeration, wind power triggered significant increases of output, through an additional effect higher than 50%, as well as a contribution to the regional GDP which reached a peak of 1.2% in 2005. Albeit, the sector is capital intensive and the total job creation reached 0.5% of the total regional employment in the same year. However, the sectoral employment increase in some branches affected directly by the stimulus evolves between 6% and 18% of the total sectoral employment. The indirect employment increase in R&D activities reached 5.3% of the sectoral employment. Hence, wind power could constitute an alternative to traditional declined agglomerations with positive effects on production and employment in industrial as well as knowledge based activities.

Given common singularities in the production structure among peripheral regions, this analytical framework helps explain sectoral linkages, its potentialities and the socioeconomic impacts in those kinds of regions. In spite of these commonalities, the estimations and the results of this paper should be regarded as general frame because the production structure differs among peripheral regions.

Future extensions should give more insights into the adoption of new technology and standards, as well as the regional clustering phenomenon derived from the emergence of wind power. Moreover, the crowding out effect between wind energy and conventional sources is also an interesting issue for further developments.

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