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The region matters: A comparative analysis of regional energy efficiency in Spain

María J. Ruiz-Fuensanta

Departamento de Economía Española e Internacional, Econometría e Historia e Instituciones Económicas, Universidad de Castilla-La Mancha, Ronda de Toledo s/n, 13071 Ciudad Real, Spain

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ABSTRACT

Owing to its strategic nature, the Spanish energy policy is primarily the responsibility of the central state. In spite of this, the Spanish legal code does in fact also confer certain powers to territorial governments in Spain, the Autonomous Communities. The objective of this work is specifically to investigate the differences between the energy performance of Spanish regions, which may be a consequence of specific features of their productive structures and resource endowments, in addition to the specific decisions adopted by each of them within the scope for action that they have in this area. With this aim in mind, we intend to calculate the inefficiency levels of Spanish regions as regards their use of various energy sources during the period 2003–2008, by estimating an environmental directional distance function. The results obtained confirm the existence of significant differences in the behaviour and evolution of regional energy efficiency and point to the need to pay more attention to energy planning in this territorial sphere.

1. Introduction

Energy-related themes are currently, either directly or indirectly, a prominent source of concern for economic and social agents, and consequently also in the political debate. On the one hand, the exhaustion of fossil fuels, the permanent reluctance to increase the use of nuclear energy and the growing concern over the deterioration of the environment are factors that have conditioned both the search for alternative sources of renewable and less contaminating energy and the more efficient exploitation of traditional sources of energy. On the other, the generic objective of monetary savings also plays a role, indirectly stimulating the efficiency of energy consumption at different levels.

The unquestionable importance of attaining sustainable development have led the current objectives of energy saving and efficiency to be expressly incorporated into the basic rules and laws that regulate the energy sector in Spain, in which it is established that the responsibility for attaining these objectives lies not only with the Central Administration but also with the AC (Autonomous Communities). Thus, for example, Law 54/97 of the Electricity Sector states that, independently of the competences attributed to the State General Administration, the Autonomous Communities will be responsible for "*The fomentation of the renewable energies of the special regime and energy efficiency in their Community's territory*". In accordance with this statement, the *Action Plan 2005–2007 of the Strategy for Energy Saving and Efficiency in Spain 2004–2012 (E4)* [21] directly involves the ACs in its execution, and moreover specifies criteria regarding collaboration between the central government and regional administrations in each policy area. The success of the results obtained by means of the co-management procedure, has prompted the *Action Plan 2008–2012* [22] to continue with the same principles of performance.

The idea of the need for the participation of the regions in the planning and implementation of measures aimed at energy saving is highlighted in the Green Book on energy efficiency [4], in which the European Commission explicitly states that the initiatives developed in this respect at community and national levels will only be effective if they are supported by action taken in the local and regional sphere. Moreover, certain measures may be more effective when managed at lower administrative levels owing to their closer proximity to their final recipients [2].

In response to this mandate of co-participation in the management of energy-related issues, Spanish regions have, within the limits of their competences, set up their own energy plans and adopted regulations in order to improve energy efficiency and to

E-mail address: MariaJesus.Ruiz@uclm.es.

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reduce pollutant emissions.[1] In this regard, some think that in a country with a high degree of administrative decentralization as Spain, the reduction of pollutant emissions can be addressed more effectively at regional than at national level [29]. However, despite the important role that regions seem to play in the process of improving energy efficiency, it is surprising that most empirical studies that address this particular aspect mainly refer to the national level, while few adopt a lower level of analysis. The exception is the growing number of studies analyzing regional energy efficiency in Asian countries, mainly China. For example, Hu and Wang [13] explore the total-factor energy efficiency of 29 administrative regions in China from 1995 to 2002 using the DEA (data envelopment analysis). Zhang and Choi [34] also use the DEA model to analyze the energy efficiency of 30 Chinese provinces during 2001–2010 but, in this case, they take into account the impact of undesirable outputs. Lin and Du [18], in turn, use a parametric metafrontier approach based on the Shephard energy distance function to investigate the regional efficiency in China from 1997 to 2010. Examples of other works that also investigate the regional energy efficiency in China include Li and Hu [17], Wang et al. [30] and Yang et al. [32].

For Japan, Honma and Hu [11] employ the total-factor energy efficiency model obtained through DEA to evaluate the energy efficiency of 47 prefectures in Japan for the period 1993–2003. More recently, these authors use stochastic frontier techniques to calculate total-factor energy efficiency scores for the same Japanese regions during the period 1996–2008 [12]. And Hu et al. [14] apply the four-stage DEA procedure, controlling for the effects of external environments, to calculate the energy efficiency of 23 regions in Taiwan from 1998 to 2007.

Despite the different methodologies used and the different geographical scope, all these studies conclude that energy utilization efficiency varies a lot among regions.

To the best of our knowledge, for the Spanish case the only study that introduces a regional dimension in the analysis is that of Esteban et al. [7]. In their research the authors measure the sectorial and regional energy efficiency by estimating a stochastic frontier Cobb–Douglas production function using micro data from a cross-section of Spanish manufacturing firms. Besides labour and capital costs, the authors use advertising expenditures and energy consumption as inputs into the production function. Based on the estimated frontiers, they obtain the conditional demand function and relative efficiency ratios for each production factor. Their results show that, in effect, not all the Spanish regions exhibit the same efficiency levels as regards the utilization of energy inputs in the industrial sector.

Although the work of Esteban et al. [7] represents a noteworthy attempt to assess regional energy efficiency in Spain, it has some limitations, such as its cross-sectional approach and the fact that it only takes into account the activity of industrial firms, leaving aside other important energy-consuming sectors, such as transportation and residential. Another important shortcoming is that the model does not incorporate undesirable output emissions when calculating the efficiency scores, so that the obtained values can be misleading in a context of growing social and political concern about an environmentally-friendly energy consumption.

In this paper, the above problems are overcome, as it will be explained below. The purpose of the present study is specifically to contribute towards a better understanding of the differences that may exist in the energy performance of Spanish regions as a consequence of, among other factors, the scope for action that they have in this area. With this aim in mind, we propose to calculate regional inefficiency scores on the use of different energy sources through the employment of an environmental directional distance function [8]. This analytical approach expressly takes into consideration the fact that economic activity not only results in the obtaining of desirable outputs —the goods and services produced— but also has parallel negative effects, such as the emission of CO_2 and greenhouse gases into the atmosphere. In addition to this, the principal advantage of the directional distance function is its flexibility, since it does not impose the assumption of proportionality on the increase of desirable outputs and the reduction of undesirable outputs as a result of applying the production technology to the set of inputs.

On the other hand, the model is estimated on data from the 17 Spanish Autonomous Communities during the period 2003–2008. The panel structure of the sample has several methodological advantages over cross-section or time-series data, such as the possibility to control for region- and time-invariant variables or unobserved heterogeneity across regions [1].

As mentioned previously, in this work we shall use this methodological approach to quantify the levels of energy efficiency in Spanish regions. Details of the model used are provided in the following section, along with a description of the fundamentals of the environmental directional distance function of Färe et al. [8]. The data used in the estimation are then described in Section 3, while the results obtained are presented and commented on in Section 4. Finally, the last section contains a summary of the main conclusions extracted.

2. Description of the model

2.1. Theoretical approach: the environmental directional distance function

The energy efficiency of Spanish regions will be measured using the directional output distance function proposed by Ref. [8]. The principal advantage of this way of representing production technology is that it expressly considers the joint production of desirable and undesirable outputs as a result of the production process. More specifically, the directional output distance function makes it possible the simultaneous expansion in desirable outputs and contraction in undesirable outputs for a given level of inputs.

The starting point used to explain the fundamentals of the directional distance function will be the set of production possibilities P(x) which represents the quantity of output that can be obtained from a given input vector $x \in \Re_+^N$. Within the achievable output, it can be distinguished the set of desirable outputs, denoted by the vector $y \in \Re_+^M$, and a vector of undesirable byproducts $b \in \Re_+^J$, such that:

$$P(x) = \{(y,\ b) : \text{x can produce } (y,\ b)\}$$

P(x) is considered to fulfil the standard axioms of a production technology.[2] The assumption of Null-Jointness is also accepted, according to which:

$$if\,(y,b) \in P(x)\ \ and\ \ b = 0, \quad then\ y = 0$$

[1] Ten of the seventeen Spanish Autonomous Communities have their own energy plan. These are Andalusia, Aragón, Baleares, the Canary Islands, Cantabria, Catalonia, the Community of Valencia, Madrid, Navarra and the Basque Country; moreover, the regions of Andalusia, Castilla–La Mancha and Murcia have approved laws on the promotion of renewable energy and energy efficiency.

[2] For details on the properties that a production technology should satisfy, see Ref. [27].