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Determinants of the European electricity companies efficiency: 2005–2014

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ABSTRACT

The growing dependence of economies on electricity makes essential the improvement of the power sector efficiency levels. This study aims to assess the factors that influence the efficiency of companies operating in the European electricity sector. To this end, a Stochastic Frontier Analysis has been applied to 4639 companies, located in 26 European countries, over the 2009–2014 period. Based on the results, it would be advisable, for all electricity subsectors, to reduce the level of indebtedness and to increase the firm size in order to enhance the efficiency levels. The results also show how the activity diversification and the company age affect firms' performance depending on the subsector.

1. Introduction

All economies around the world are electricity-dependent [1]. The invoice of electricity for companies and households are of high value and represent a large proportion of their costs. Based on these facts, a wide range of literature has emerged from the points of view of production (supply) and consumption (demand), in both technical and economic terms.

New resources have been found, and new transformation techniques have been developed. Nowadays, energy efficiency considering the environment is a goal [1–3], and all involved have too much to do. At the end of the tail, (industrial and household) consumers should reduce their consumption by acquiring more efficient machines and products, or just by turning off lights or switching off devices when they are not necessary. In the middle, the transmission and distribution companies should reduce losses and design efficient networks. Power generators should look for more efficient and lesser pollutant resources and systems of production (transformation). Finally, regulators must encourage innovative activities and promote efficient consumption and production of electricity [3,4].

Assessing the factors those affect efficiency levels will allow the companies of the sector to adapt their behavior and, thus, to know the path to reach an efficient management system or, at least, to improve it. Moreover, the analyses of efficiency determinants will allow the regulator to find gaps on the supply side and to legislate accordingly. Thus, the primary objective of this research is to ascertain the determinants of technical efficiency for electricity companies in Europe. To this end, a parametric methodology of stochastic production frontiers has been applied to a sample of generation, transportation, and distribution companies in the period 2005–2014.

The rest of this paper is structured as follows: the second section reviews the existing literature on efficiency undertaken in the electricity sector. The third part describes the theoretical model to be used, and the fourth section outlines the data collected for the study and how it was processed. The fifth and sixth paragraphs explain the results obtained in this investigation and the conclusions of the study.

2. Literature review

The application of efficiency analysis to the electricity sector is of great interest given its public service nature and the high dependence of countries and regions on the sector for economic development. For this reason, numerous studies have been undertaken. However, researchers have focused mainly on the regulation and privatization of the sector.

Several studies have analyzed technical efficiency of the electricity sector, and significant differences among countries have been found [5,6]. Some studies have highlighted the excess of capital [5] and labor [7] as drivers of inefficiency. However, the proportion of technicians (qualified labor) increases efficiency [8].

Interesting analyses about the determinants of efficiency show negative influence in the energy sales rate for residential consumption and positive influence of the calorific power of the energy source used in production and of the use of capital [9].

The impact of the age of the firm on technical efficiency has been assessed in the literature, but authors have not reached consensus on it (positive impact [8], negative impact [7], no impact [9]). The same applies to the effect of size on utilities firm efficiency where authors have found evidence of both positive [10,11] and negative impact [7].

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Regulation has also been found as an influencing variable on many economic studies on the electric utility industry (i.e. [4,8,12–14]). Deregulation opened the doors for electricity firms to diversify into both related businesses (i.e., gas) and unrelated businesses (i.e., telecommunications). In this vein, few studies have investigated the effect of diversification. Wilson [15] expressed the idea that related diversification was beneficial because of a synergy effect. However, Sueyoshi et al. [16] estimated (using a DEA analysis) the financial performance of 104 US utility firms and found no evidence of synergy effect.

The indebtedness level is a key factor in capital-intensive industries, where fixed assets play a major role. Despite this, the literature is very scant concerning this issues. To overcome this lack of scientific research, this paper aims to evaluate the impact of indebtedness on the efficiency of the electricity sector.

3. Methodology

Since Farrel [17] introduced the study of the production function, a large body of literature has emerged aimed at studying companies' technical efficiency. Once the production frontier (the maximum production hypothetically achievable for each combination of quantities of productive factors) has been defined, technical efficiency can be measured as the ratio of actual production to the production frontier [18] using either deterministic or stochastic frontier methodologies. Both deterministic and stochastic frontiers have advantages and disadvantages.[1] A deterministic frontier obtained using DEA (Data Envelopment Analysis), avoids the need to define a functional form at the beginning of the calculation process. However, analysis with stochastic frontier (versus deterministic frontier) is more flexible and divides the random component of the regression into technical inefficiency on the one hand and a random error component (outside the company's control) on the other.

Following the proposal of Aigner et al. [19] and Meeusen and Van Den Broeck [20], which shaped stochastic production frontiers, several changes have been made to the model. The contributions of Cornwell et al. [21] and Kumbhakar [22] to provide temporal variation to technical efficiency are noteworthy. Aigner et al. [19] suggested a model with semi-normal distribution of the effects of inefficiency (assuming a zero mean) and Stevenson [23] suggested normal distribution truncated at zero (assuming a non-zero mean) as a generalization of the previous model. Pitt and Lee [24], Battese and Coelli [25] and Lee and Schmidt [26] developed various proposals for panel data processing to analyze technical efficiency using stochastic frontier production models. Battese and Coelli [27] empirically developed and implemented the procedure for single-stage[2] calculation of the stochastic frontier production model for unbalanced panel data previously developed by the same authors [25].

As it is considered that non-controllable effects could be hidden in the production of companies in the European electricity sector, it is proposed the use of a model with stochastic frontier function to measure their technical efficiency. To this end, the use of the model developed by Battese and Coelli [27] is suggested, which allows for the estimation of the companies' varying technical efficiency over time, simultaneously with the determinants of said efficiency, in a single-stage process.

Expression (1) represents the production stochastic frontier model and expression (2) represents the model of inefficiency determinants by the methodology of Battese and Coelli [25]:

$$Y_{it} = f(\beta_j; X_{itj}) + v_{it} - u_{it} \tag{1}$$

$$u_{it} = \sum_k \delta_k z_{itk} + w_{it} \tag{2}$$

where, for the i-th company ($i = 1, \ldots, N$) in year t ($t = 1, \ldots, T$) of observation: Y is the value of production; $f(\beta_j;X_j)$ is a functional form of linear production depending on the amount of the j-th factor used in production and unknown parameters subject to estimation respectively X_j and β_j); v represents the stochastic effect on production (assumed iid as per $N(0,\sigma_v^2)$); and u represents the technical inefficiency in its productive activity (assumed iid as a non-negative truncated distribution function $N(\mu, \sigma_\mu^2)$).

With $k = 0, \ldots, K$, z_k is the *k-th* determining factor of inefficiency; δ_k are unknown parameters subject to estimation; and w is a random variable assumed to be distributed according to a half-normal (zero mean) distribution with variance σ_ω^2.

The model, in accordance with the approach of Battese and Corra [28], uses a reparametrization of the variance of the stochastic terms and inefficiency defined by expressions (3) and (4):

$$\sigma^2 = \sigma_v^2 + \sigma_\mu^2 \tag{3}$$

$$\gamma = \frac{\sigma_\mu^2}{\sigma_v^2 + \sigma_\mu^2} \tag{4}$$

The γ parameter takes values in the range [0,1]. A value close to zero would lead to the conclusion that the effects of inefficiency of the model are negligible compared to the factors outside the company's control. Conversely, a value of the γ parameter close to one would indicate the irrelevance of the stochastic term versus the effects of inefficiency.

Once the defined model has been estimated, the calculation of the technical efficiency of each company in all the observations of the period studied (TE_{it}), follows the approach shown in expression (5):

$$TE_{it} = \exp(-u_{it}) \tag{5}$$

The estimation method of the model is the maximum likelihood method derived by Battese and Coelli [29].

4. Data

The companies in the electricity sector have distinctly different technical characteristics in accordance with the end goal of their principal activity which requires us to make an initial division into four subsectors: production, transmission, distribution, and trade:

- The production subsector transforms the energy stored in a primary source into electricity. This subsector uses a wide range of technologies depending on the primary source in question.
- The transmission subsector performs all activities involved in transferring the electrical energy produced from the point of generation to the distribution network, linking the production systems of the different regions comprising the territory. The electricity transmission network consists of towers and wiring – electrical substations and transport lines – whose main task is to increase or decrease the voltage used to transport energy in order to reduce losses.
- The distribution subsector takes electrical energy from the transmission network and directs it to the final point of use. It is important to note that distribution efficiency lies not only in the ability to use the minimum possible resources to obtain a certain level of production, but that this ability depends on the building format (population density) of the area being supplied [10,30,31].
- The trade sector acts as a mediator between consumers and

[1] These advantages (and disadvantages) of one methodology over the other make it difficult to researchers to reach a consensus on the appropriateness of one methodology of analysis over the other, and the choice lies in the hands of the researcher, based on the existence or otherwise of factors outside the company's control which affect the production levels actually obtained.

[2] There is evidence [45] in favor of using the single-step calculating method as it eliminates bias and possible contradictions introduced by the two-stage calculation methodology. This is a result of considering the inefficiency term as an independent and identically distributed random variable (iid) in the first stage, whilst in the second stage, when a prediction model has been specified, the variable is no longer considered as such.