Scope, Diversification and Scale Economies in the Electricity Industry: A Non-Parametric Frontier Approach

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Abstract

This paper estimates the degree of economies of scope, diversification and scale in the Spanish electricity industry by means of non-parametric frontier techniques over the period 1991-1997. Our results show that there exist economies of scope between generation and distribution of power as well as economies of product diversification at the generation stage. Particularly, the hypothetical vertical unbundling and the horizontal product specialization of existing diversified firms would have raised the total operating costs of the sector by 4.7 and 3.5 percent respectively. Additionally, size appears to be irrelevant provided that vertical scope and product-mix are preserved. Further, it is estimated that overall operating costs of the sector could be reduced by 2.7% by partitioning each of the diversified firms down the middle. Such a fragmentation, in addition to improve firms’ scale efficiency, would have helped to create a more competitive market structure.

Key words: Economies of Scope, Diversification, Scale Efficiency, Electricity.

JEL Classification: D24, L94, L11

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1. Introduction

The worldwide wave of liberalising reforms in the electricity industry have been aimed at introducing competition in a sector traditionally organised around monopoly, public ownership and intense regulation. The pro-competitive potential of these reforms is fundamentally determined by the market structure. On the one hand, it is obvious that the existence of a sufficient number of competitors is an indispensable requisite for developing an effective competition in any industry. On the other hand, in the electricity sector the effective separation between regulated and non-regulated business is essential to attain the benefits of competition.¹ As in other countries, in Spain the high level of horizontal concentration together with firms’ vertical integration are considered the main obstacles for the competitive functioning of the electricity market (Arocena et al 1999, Fernández-Ordóñez 2002, Ocaña 2003).

Regarding horizontal concentration, this may be reduced by increasing the number of competitors through the partition of large firms in smaller units. This type of intervention, carried out in Britain during the nineties, seems to be the most effective when new entry is difficult. Nevertheless, the (technically) efficient number of firms as well as their degree of vertical integration depends on the magnitude of the economies of scale, scope and diversification economies. Hence, if scale and horizontal diversification economies are limited or negligible, the break-up of large firms in smaller units will have a positive effect on reducing market power without damaging the costs of the resulting firms. On the contrary, if such economies are significant, the partition will lead to efficiency losses (and cost increases) that could counterweight the potential benefits derived from a more competitive functioning

¹ Otherwise, a vertically integrated company would be able of (i) cross-subsidizing the competitive part of the business with profits from the regulated business; (ii) distorting competition by favouring their associated business over competitors, whether in quality of service or in the price charged for using the system. The threat of such anticompetitive behaviour is an effective entry deterrent.
of the market.

A similar argument applies to the vertical scope of the firm. If power could be efficiently supplied by means of specialized firms competing in their respective stages of the business, vertical separation could help to increase the competitive pressure in the market without cost penalties. Conversely, if vertical or scope economies across stages are important, potential benefits of unbundling could be counterbalanced by the loss of productive efficiency.

Defenders of large firms and vertical integration remark the existence of economies of scope and scale economies, while advocates of unbundling cite the benefits of competition and deregulation. Therefore, the estimation of such economies has important policy implications on further restructuring (or not) (Pittman, 2003).

Most of previous literature confirms that economies of scale are exhausted for relatively small sizes, both at plant and firm level (see Ramos-Real, 2005 for a comprehensive review). By contrast, the majority of empirical work suggest the existence of significant vertical economies across generation and transmission/distribution stages, as well as horizontal diversification economies at generation and distribution stages (Kaserman and Mayo 1991, Gilsdorf 1995, Lee 1995, Thompson 1997, Hayashi et al 1997, Kwoka 2002, Nemoto and Goto 2004). These economies arise from various sources: (i) joint planning and investment decisions regarding plant size/location and transmission/distribution systems; (ii) reduction of transaction costs associated to better information about downstream demand and load; (iii) coordination of scheduled shutdowns for maintenance (iv) reduction of the overhead costs by sharing labour (see Kwoka, 2002).

To our knowledge, Jara-Díaz et al (2004) is the only work that estimates economies of integration in the Spanish electricity sector. These authors estimate a multistage-multiproduct quadratic cost function over the period 1985-1996. Their results show that joint generation
and distribution of power saves around 6.5% of costs, while the economies of integrating various forms of generation saves up to 28.1% of costs.

The objective of this work is the estimation of these economies by means of an alternative approach. Particularly, we use non-parametric methods based on linear programming models. This approach presents some attractive features over the traditional cost function estimation. First, it implies the estimation of a frontier rather than the non-frontier cost function, which implies to implicitly assume that firms are efficient. Second, we do not impose a priori any functional form relative to the underlying technology (i.e. quadratic, translog, etc.). Finally, specific benchmark frontiers are constructed for diversified and specialized utilities. This avoids a general assumption of parametric approaches: the definition and estimation of identical forms of cost functions regardless of whether outputs are jointly produced or separately produced.

The paper is organised as follows. Section 2 reviews the theoretical background of economies of size. Section 3 describes the non-parametric frontier methodology we use to estimate the economies of integration. Section 4 presents data and variables while results are displayed in Section 5. Final section summarizes the empirical results and makes conclusions.

2. Economies of scope, diversification and scale: Theoretical background. 
Firm boundaries and, consequently, the configuration of the industry, is largely determined by the properties of the firms’ cost function. In this respect, the notion of cost subadditivity is particularly relevant. A cost function $C(y)$ is said to be subadditive at the output level $y$ if for any and all quantities of outputs $y_1, \ldots, y_n$, $y_j, j = 1, \ldots, n$, such that $\sum_j y_j = y$, we have $\sum C(y_j) > C(y)$. That is, if the cost function is subadditive, it is more cost efficient to combine the output bundles produced by several firms into a single bundle to be produced by one larger firm. Further, if the firms’ cost function is subadditive over the entire relevant
range of outputs, then the industry is said to be a natural monopoly since a single firm can produce all relevant output vectors more cheaply than two or more firms. Alternatively, if the cost function were superadditive it would be cost efficient to break up the output of a large firm into several bundles to be produced by a number of smaller firms.

Cost subadditivity shapes both the horizontal and vertical boundaries of the firm. Thus, it is related to the degree of (i) economies of scale; (ii) vertical (or multistage) economies of scope across stages; and (iii) horizontal (or product-mix) economies at one stage.

2.1 Multistage scope economies: Vertical integration.

Economies of scope arise from cost savings obtained from the joint production. That is, it is more efficient to produce an output bundle by a single diversified firm than splitting up the production of each output, or subset of outputs, between separate specialised firms. Following Baumol et al (1982 p.71-72), let $\mathcal{N}$ be the set of outputs produced by a firm. Consider a subset of the firm’s outputs $\mathcal{S} \subseteq \mathcal{N}$. Let $P=\{T_1,T_2,\ldots,T_k\}$ be a non-trivial partition of $\mathcal{S}$. That is, $\bigcup_{i} T_i = \mathcal{S}$, $T_i \cap T_j = 0$ para $i \neq j$, $T_i \neq 0$, $k > 1$. There are economies of scope at $\mathcal{y}$ with respect to the partition $P$ if $\sum_{i=1}^{k} c(y_{T_i}) > c(y)$. Diseconomies of scope occur if the inequality is reversed. Economies of scope is a necessary –though no sufficient- condition for subadditivity.

Thus, for the two-output case $(y_1,y_2)$ there are economies of scope if

$$C(y_1, y_2) < C(y_1,0) + C(0,y_2)$$

[1]

When $y_1$ and $y_2$ are outputs corresponding to adjacent stages in the vertical chain (i.e. generation and distribution of electricity), [1] reveals the existence of vertical (or multistage) scope economies (Kaserman and Mayo, 1991).
Note that economies of scope is a restricted form of subadditivity, where the output vectors of specialized firms are restricted to be orthogonal to one another, that is, such that \( y_i \cdot y_j = 0, \ i \neq j \). Thus, for the three-output case \( y = (y_1, y_2, y_3) \), economies of scope are said to exist with respect to partition \( P = \{T_1, T_2\} \), \( T_1 = (y_1, 0, 0), \ T_2 = (0, y_2, y_3) \) if

\[
C(y_1, 0, 0) + C(0, y_2, y_3) > C(y_1, y_2, y_3)
\]

The degree of scope economies at \( y \) relative to the partition \( P \) is defined as

\[
SC_P(y) = \frac{C(y_T) + C(y_{N-T}) - C(y)}{C(y)} \quad [2]
\]

That is, it measures the relative increase in cost that would result from dividing the production of \( y \) into product lines \( T \) and \( N-T \). Such a fragmentation of the firm increases, decreases, or leaves unchanged the total cost, as \( SC(y) \) is greater than, less than, or equal to zero, respectively.

2.2 Economies of (horizontal) diversification or product-mix economies.

Grosskopf et al (1992) define economies of diversification as the cost savings that may result from a firm’s increasing the number of simultaneously produced (different) outputs. Consider the three-output case and two firms (A,B). Additionally, let us assume that outputs 1 and 2 are produced in the upstream stage (i.e. hydroelectric and thermal power generation) while output 3 is the downstream product (i.e. power distribution). Firm A specializes in the production of output 1, firm B specializes in the production 2, while both firms produce some of output 3. That is, both firms are vertically integrated but are specialized in the upstream stage. Economies of diversification are said to exist if

\footnote{This is only one possible partition of the output vector. Scope economies could be calculated relative to any non-trivial partition. For example, \( P' = (T_1, T_2, T_3) \) where \( T_1 = (y_1, 0, 0), \ T_2 = (0, y_2, 0), \ T_3 = (0, 0, y_3) \), which would imply full specialization.}
Diseconomies of diversification occur if the inequality is reversed. For the three-output case, the degree of economies of diversification can be measured as

\[
DIV(y) = \frac{c(y^A_1, y^A_3) + c(0, y^B_2, y^B_3) - c(y^A_1, y^B_2, y^A_3 + y^B_3)}{c(y^A_1, y^B_2, y^A_3 + y^B_3)}
\]

If \(DIV(y)\) is positive (negative) then economies (diseconomies) of diversification exist at \(y\). If \(DIV\) is zero, costs are additive at \(y\). \(DIV(y)\) compares the costs of two vertically integrated firms each producing some unique output to the cost of a single multiproduct firm which produces all of the products at the same levels of total output.

It is therefore, an appropriate measure to evaluate decisions on expansion of product line, as well as to assess the cost consequences of merging (breaking up) firms with diverse product mix.

\[2.3\text{ Multiproduct Scale Economies}\]

Multiproduct scale economies are said to exist when total costs go up less than proportionally when the output of all products is increased by the same proportion. This is equivalent to decreasing ray average cost. Ray average cost is the multiproduct equivalent of average cost as defined for the single-product firm, and is defined as the average cost of producing the fixed bundle for a given scale of production. That is, the measure of total output when there are \(N\) products is done by fixing a bundle of the \(N\) products and the measure of output is then the number of bundles produced. This is equivalent to assuming that output is produced in fixed proportions and the measure of output is then the scale of production. The degree of multiproduct scale economies is given by

\[
MSE(y) = \frac{C(v^A, y) + C(v^B, y) - C(y)}{C(y)}
\]
where \( v_i \) denotes output proportions, with \( 1 > v_i > 0 \) and \( \sum v_i = 1 \). \( MSE(y) > 1 \) (<1) implies multiproduct economies (diseconomies) of scale. When \( RAC \) is decreasing at \( y \), it is not possible splitting up the output bundle \( y \), holding the mix of products constant, without increasing total cost.\(^3\)

Figure 1 depicts total cost and average cost along the ray \( OR \), which keeps constant the proportion in which product 1 and product 2 are produced \( (y_2/y_1) \). \( RAC \) reaches its minimum at the output \( y = y^o \) at which the ray \( OT \) is tangent to the total cost surface in the hyperplane erected on \( OR \). Any output vector to the left or right of \( y^o \) presents higher average costs along \( OR \). Putting in other words, only \( y^o \) is scale efficient in \( OR \), it is the optimal scale of production for such output proportion \( (y_2/y_1) \). For example, the partition of a single firm producing \( y^o \) in two identical firms by dividing \( y^o \) down the middle (i.e. \( v = 0.5 \) resulting in two firms producing \( y^o/2 \)) along \( OR \), will increase \( RAC \) due to the scale inefficiency.

[Insert Figure 1]

3. **A non-parametric approach to the measurement of economies of integration.**

Most empirical analysis on scope, scale and product-mix economies typically relies on the estimation of multiproduct cost functions. Ramos-Real (2005) provides a recent and comprehensive review of this approach in the electricity industry. Nevertheless, there have been various adaptations of the non-parametric frontier methodology to estimate economies of scope and diversification (Färe, 1986; Färe et al, 1994). The linear programming approach has been applied to municipalities (Grosskopf and Yaisawarng 1990), banks (Ferrier et al, 1993), hospitals (Prior, 1996; Fried et al, 1998, Kittelsen and Magnussen, 2003) and cogeneration systems (Kwon and Yun, 2003).

\(^3\) Decreasing ray average costs up to \( y \) imply *ray subadditivity* at \( y \) (Baumol et al, 1982 p.175).
Let $y = (y_1, \ldots, y_M) \in R^M_+$ be the output vector produced by means of the input vector $x = (x_1, \ldots, x_N) \in R^N_+$. Production technology can be represented by the input requirement set, which includes all input vectors yielding output $y$. $L(y) = \{ x : x \text{ produce } y \}$. Technology can also be completely described by the cost function

$$C(y, w) = \min_{x \in L(y)} \{ wx' : x \in L(y) \}, \quad [5]$$

where $w = (w_1, \ldots, w_N) \in R^N_+$ is the vector of input prices. The cost function describes the minimal costs to produce the corresponding combination of outputs with given input prices.

Assume that there are two output bundles, named $y^A$ and $y^B$, which can be either jointly or individually produced from the same inputs $(x_1, x_2)$, from diversified or specialized firms respectively. Let $L(y^A, y^B)$ denote the input combinations necessary to jointly produce $y^A$ and $y^B$. In Figure 2 this input set is the area bounded from below by the isoquant $\text{Isoq}-L(y^A, y^B)$, which is the frontier of technology of the diversified firms. Additionally, in Figure 2 two isocost lines are indicated given the input prices $w = (w_1, w_2)$. The lower one represents minimal cost relative to $L(y^A, y^B)$.

Let us consider a diversified firm like $F$. This firm is inefficient because it could produce $(y^A, y^B)$ with less consumption of both inputs (technical inefficiency), and consequently, with lower total costs. The overall economic inefficiency of firm $F$ can be represented by the distance to the isocost line $C_d C_d'$. Thus, the ratio $O F_F / O F$ measures the reduction in costs attainable by firm $F$ once both technical and allocative inefficiency are eliminated.

[Insert Figure 2]

On the other hand, the isoquant labelled by $\text{Isoq}-L(y^A) + L(y^B)$ and the isocost line $C_s C_s'$ represents the efficient frontier for separate production of $y^A$ and $y^B$. It is an additive frontier constructed by summing the inputs quantities employed by the specialized firms. It is easy to see that the inefficiency of our diversified firm $F$ is smaller relative to this additive frontier.
This is measured by the distance $\frac{OF^*_S}{OF}$ which is smaller than $\frac{OF^*_d}{OF}$. Therefore, given input prices $w$, the minimum cost attainable from producing $(y^A, y^B)$ in separate firms is higher than their joint production. In other words, the cost of splitting up the production of $(y^A, y^B)$ into specialized firms, is equal to the distance $\frac{OF^*_d}{OF^*_S} = \frac{C^*_d}{C^*_S}$

The type of (dis)economies behind this distance is given by the characteristics of the specialized vectors used to construct the additive frontier $L(y^A)+L(y^B)$. For example, if output vectors $y^A$ and $y^B$ are orthogonal, the distance $\frac{OF^*_d}{OF^*_S}$ accounts for (dis)economies of scope. Otherwise, it may account for (dis)economies of diversification as defined above.

In summary, we can estimate the efficiency gains due to integration by comparing the cost frontier of joint production $C(y^A, y^B)$ with that corresponding to separate production $C(y^A)+C(y^B)$.

Let $Y$ be the matrix $MxK$ of observed outputs and $X$ the $(N\times K)$ matrix of observed inputs. That is, there are $M$ different outputs and $N$ different inputs for each of $K$ firms. We construct a piecewise linear reference technology based on these observed outputs and inputs by taking convex combinations of the observed data points and their extensions

$$L(y) = \{x: Y \cdot z \geq y, X \cdot z \leq x, z \in \mathbb{R}^K_+\}$$

where $L(y)$ is the input requirement set for output vector $y$ and $z$ is a $Kx1$ vector of intensity variables from activity analysis. The only restriction on the $z$ variables is that they be nonnegative, the technology represented by (6) satisfies constant returns to scale (CRS). This implies that scalar expansions and contractions of the observed input-output vectors are feasible. Constant returns to scale represents long-run optimal scale (consistent with minimum average costs for the firm with the traditional U-shaped average cost curve.

The minimal costs may be calculated as the solution to the following linear programming problem for each observation $k$ (Färe et al. 1994):
\[
\min(y_k, w_k) = \min_z w_k \cdot x_k
\]
s.a.
\[
Y z \geq y_k \quad \text{[7]}
\]
\[
X z \leq x_k
\]
\[
z \in R_{+}^K
\]

In our specification, we assume that all firms face identical input price vector \( w \). We do not find reasons to believe that there exist differences in prices for contracting labour, capital and fuel amongst the electric utilities in Spain. More precisely, if one firm actually pays higher interest rates, salaries and/or fuel prices than its competitors for the same quality of inputs is exclusively due to its inefficiency in contracting these factors, but not the result of facing different access conditions than its counterparts. Similarly, it is rarely assumed that firms face different quality of inputs. In such a case, minimization of scalar costs, \( c \), rather than \( wx \) yield the same efficiency, and problem [7] is equivalent to

\[
D^d \left( y_k^d, c_k^d \right) = \min_{\lambda} \lambda
\]
s.a.
\[
Y z \geq y_k^d \quad \text{[8]}
\]
\[
C z \leq \lambda c_k^d
\]
\[
z \in R_{+}^K
\]

where \( C \) is the \( I \times K \) vector of observed costs and \( c_k \) is the scalar-valued cost for firm \( k \). Superscript \( d \) stands for the sample of diversified firms. Similarly, we calculate the efficiency of the diversified firm relative to the additive frontier by solving

\[
D^S \left( y_k^d, c_k^d \right) = \min_{\lambda} \lambda
\]
s.a.
\[
Y^S z \geq y_k^d \quad \text{[9]}
\]
\[
C^S z \leq \lambda c_k^d
\]
\[
z \in R_{+}^K
\]
where superscript \( s \) denotes the set of the additive combination of specialized firms. Thus, \( Y^s \)
is the \((M \times K)\) output matrix and \( C^s \) is the \((1 \times K)\) vector of total cost, both referred to the
additive data set.

4. Data and variables

Our data set consists of production levels and costs of twelve Spanish electrical utilities
throughout the period 1991-1997. These firms accounted for the totality of power generation
and distribution in Spain over the period.

For the generation outputs, we consider the megawatts hour of hydroelectric (HYDRO)
and thermal power (THERMAL).\(^4\) Regarding distribution/supply, we include low voltage
(LV) and high voltage (HV) power distribution, both measured in megawatts hour, as well as
the total number of customers (CUSTO).\(^5\) Finally, net operating costs (that is, exclusive of
purchased power) were measured at constant 1990 prices and calculated as the sum of fuel
costs, personnel costs, depreciation and other external operating costs. Data were drawn from
the National Energy Commission (CNE, 1997) and the annual reports of companies. Table 1
shows the output bundles and costs for each company over the period 1991-1997.

[Insert Table 1]

As a first step, firms were classified in four groups, according to their degree of business
specialization.

Group 1. Generating firms only, that is, firms that do not distribute the power they
produce, but resale to other firms. This group is formed by only one firm, ENDESA.

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\(^4\) HYDRO figures also includes power generated from wind turbines, while THERMAL covers power produced
from fossil-fuelled stations –mostly coal based- and nuclear plants.

\(^5\) In Spain, transmission -or high voltage transport- is carried out by a single firm, Red Eléctrica de España,
which at the time considered in this study was a public monopoly. Nevertheless, various utilities retained some
transmission lines which were accounted into their distribution business.
Group 2. Firms specialized in power distribution, with some percentage of power generation, being that produced mostly by hydro facilities. This group is comprised of three companies: ERZ, ENHER and HEC.

Group 3. Power generating and distributing companies with a clear thermal specialization: GESA, UNELCO and SEVILLANA.

Group 4. Diversified firms with a vertical integration ratio (generated MWh/ Distributed MWh) above 75%. This group is comprised of five firms: IBERDROLA, UNIÓN FENOSA, HIDROCANTABRICO, VIESGO and FECSA.

Next, we construct combinations of specialized firms included in 1-3 groups. Our purpose consists of creating hypothetical companies with which we can construct the additive technology $C(y,c)$, which serves as a benchmark for costs where production is organized in separate specialized firms. To this end, following Grosskopf and Yaisawarng (1990) and Ferrier et al. (1993), we construct all possible permutations of specialized firms in one group with each other, which are then added pairwise with the permutations of the other group. We form two types of composites according to the firms’ group of origin.

(i) Type A composites. They are the result of adding firms of groups 1 and 2. By means of the method referred to above, we obtain seven hypothetical companies for each year over the period 1991-1997. These composite observations have costs that are strictly additive and are used to construct an additive frontier.

The distinctive feature of these composites is that they are formed from the sum of output vectors of specialized firms that are orthogonal to one another. To be precise, almost orthogonal, since Endesa’s production of hydroelectric power is not zero, but represents about 3.5% of total utility’s generation.
suitable to measure the potential economies of scope between generation and distribution, i.e. vertical economies.

(ii) Type B composites. They are formed from additive combinations of specialized firms included in groups 2 and 3. We obtain 49 hypothetical firms for each year, which gives a total of 343 composites. The characteristic of these composites is that the aggregation of specialized firms would result in higher horizontal diversification. Unlike type A composites, output vectors of specialized firms are not orthogonal, since all these firms distribute power. The resulting additive frontier is a suitable benchmark to measure the potential economies of diversification as defined above.

5. Results
5.1 Economies of vertical integration

First, we measure the cost efficiency of diversified firms included in group 4 relative to their own technology i.e. we calculate the distance $D_d(y^d,c^d)$ by solving problem [8]. We construct the frontier using the whole sample of diversified firms as the reference production set. That is, we merge the data for all the years 1991-1997 into one set to construct an intertemporal frontier (Tulkens and Vanden Eeckaut, 1995). Additionally, we compute the average diversified firm for each year and include these seven artificial diversified firms as additional units. This results in a data set with 42 observations.

Next, we do the same thing with type A composites (49 units) and measure the cost efficiency of diversified firms relative to this additive frontier. That is, we compute the distance $D_A(y^d,c^d)$ by solving problem [9]. The degree of scope economies for each diversified firm is given by

$$SC(y^d_k) = \frac{D_A(y^d_k,c^d_k)c^d_k - D_d(y^d_k,c^d_k)c^d_k}{D_A(y^d_k,c^d_k)c^d_k} = \frac{D_A(y^d_k,c^d_k)c^d_k}{D_d(y^d_k,c^d_k)c^d_k} - 1$$

which is equivalent to [2].
Results are shown in Table 2. \( SC(y_k) > 0 \) for every diversified firm, that is, the partition of the output vector \((y^H, y^T, y^D)\) into \((0, y^T, 0)\) and \((y^H, 0, y^D)\) would result in efficiency losses, where \(y^H\), \(y^T\) and \(y^D\) stand form hydro generation, thermal generation and power distribution respectively. For example, for the average diversified firm, such a partition would increase cost by 24% due to the loss of scope economies. Table 2 also reveals wide differences between firms. Thus, the output bundle of Unión Fenosa presents the highest degree of scope economies (21.1%), while figures for the other firms range from 2.1%-8%.

Additionally, we have calculated the impact that such a fragmentation of the five diversified firms would have on the total operation costs of the Spanish electricity sector. Column 1 in Table 3 shows that this alternative would be, on average, 4.7% more expensive than keeping the diversified firms with their actual output bundles.

5.2 Economies of horizontal diversification

To estimate the diversification economies we compare \( D^d(y^d, c^d) \) with \( D^S_{SB}(y^d, c^d) \). Subscript \( B \) indicates that the additive frontier is constructed with type B composites. We compute the degree of economies of diversification for each of our diversified firms according to [3] as

\[
DIV(y^d_k) = \frac{D^S_{SB}(y^d_k, c^d_k) - D^d(y^d_k, c^d_k) \cdot c^d_k}{D^d(y^d_k, c^d_k) \cdot c^d_k} - 1
\]

As shown in Table 2, with the exception of HidroCantábrico, economies of horizontal diversification are less significant for utilities than scope economies. Further, one utility (Viesgo) does not enjoy economies of diversification while Fecsa’s are very modest (0.5%). For the average firm, the separation of the generation products into two specialized firms would increase operating costs by 17.5%. As Table 3 shows, such a partition for each of the five diversified utilities would increase 3.5% total operating costs of the electricity sector.
5.3 Scale economies

As shown before, any partition of diversified firms that implies the reduction of their vertical and/or horizontal integration would inevitably lead to a cost increase. Hence, one may ask whether it is efficient to divide the existing firms in smaller companies while keeping constant their current degree of vertical integration and horizontal diversification. This requires checking if the increase of the number of competitors is not counterweighted by the efficiency losses due to the reduction of the firms’ scale of operations. To that purpose, we divide down the middle the output bundles of the five diversified firms. Such a partition keeps constant their output proportions, and consequently, their degree of horizontal and vertical integration.

A firm operating at optimal scale is scale efficient and any deviation from the point of scale efficiency raises average costs above the minimum. Scale efficiency is computed as the distance to the optimal scale size. In Figure 1, the tangent to the total cost curve is the ray $OT$, which measures the optimal production scale at output $y^o$. Only $y^o$ is scale efficient while the vertical distance $OC/OV$ measures the scale inefficiency for $y^o/2$, which is the ratio of total costs and costs on the $OT$ ray at the output level $y^o/2$. Points on the $OT$ ray are feasible when constant returns to scale prevail. Hence, scale efficiency is computed as the ratio between the distance to the cost frontier under constant returns to scale (CRS) and the distance to the cost frontier under variable returns to scale (VRS).

Let $\varepsilon_d$ denote the scale efficiency corresponding to the original output of diversified firms while $\varepsilon_{d/2}$ that corresponding to the halved firms, then

$$\varepsilon_d = \frac{D^{crs}(y^d, c^d)}{D^{crs}(y^d, c^d)}$$

$$\varepsilon_{d/2} = \frac{D^{crs}(y^d/2, c^d/2)}{D^{crs}(y^d/2, c^d/2)}$$
Ray average cost is decreasing, increasing or constant if $\varepsilon_d/\varepsilon_d/2$ is lower than, greater than of equal to unity respectively.\(^7\) The degree of multiproduct scale economies for each firm is computed as

$$RSE(y^d) = C(y^d) \cdot \varepsilon_d - 2\varepsilon_d^{\varepsilon_d/2} \cdot C(y^d/2) \cdot \varepsilon_d = 1 - \left( \frac{D^{\varepsilon_d}(y^d/2, e^d/2)}{D^{\varepsilon_d}(y^d, e^d)} \right)$$

Results for $RSE(y)$ are shown in last three columns of Table 2. It is clear that fragmentation of firms would produce cost savings due to the improvement of scale efficiency. Thus, the break-up of the average firm into two identical firms (holding constant its original output proportions) would lower costs by 2.4% than to let it operate as a single production unit. Such a partition would improve scale efficiency of three out of five firms, while for the other two the impact would be negligible (0.1%) The overall annual cost savings for the electricity sector would represent 2.7% on average, as shown in Table 3.

**Conclusions and policy implications**

This paper has estimated the degree of economies of scope, horizontal diversification and scale in the Spanish electricity sector by means of non-parametric frontier techniques. Our results may be summarized as follows: (i) We find scope economies between generation and distribution for every diversified utility in a range of 2.1% to 21.1%. Complete vertical unbundling would have raised operating costs of the sector about 4.7 percent over the period 1991-1997; (ii) Cost savings due to the diversification of power generation accounted up to 17.5% for the average firm over 1991-1997. Thus, the eventual horizontal specialization at the generation stage would have risen the operating costs of the period by 3.5% (iii) Economies of scale are not important provided that vertical scope and product-mix are preserved. On

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\(^7\) Efficiency under variable returns to scale is computed by adding the restriction $\sum_{i=1}^{k} \varepsilon_i = 1$ to the linear problem [8]. See Cooper et al (2000) for further details.
average, overall operating costs of the sector could be reduced by 2.7% by dividing each of the diversified firms down the middle.

These results have important policy implications for the restructuring of the electric power sector. Thus, any break-up of firms implying complete vertical disintegration and/or firm’s specialization on the generation stage is expensive options in terms of efficiency losses. Therefore, the expected competitive gains of such partition should be compared with the sacrifice of vertical and horizontal economies.

By contrast, a partition of large diversified firms would be rational on grounds of economic efficiency provided that vertical and horizontal output proportions are preserved. In addition to the likely benefits from higher competition, the combined cost of the constituent smaller firms would be lower than the cost of the larger firms because of the improvement in their scale efficiency.

References


Figure 1. Ray average cost and scale efficiency.
Figure 2. Efficiency gains from joint versus separate production.
### Table 1. Descriptive statistics of outputs and cost by electric utility

<table>
<thead>
<tr>
<th>Utility</th>
<th>COST (thousand €)</th>
<th>HYDRO (GWh)</th>
<th>% HYDRO</th>
<th>THERM (GWh)</th>
<th>% THERM</th>
<th>LV (GWh)</th>
<th>% LV</th>
<th>HV (GWh)</th>
<th>% HV</th>
<th>CUSTOM (GWh)</th>
<th>% CUSTOM</th>
<th>VI ratio * (%)</th>
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Note: Average values 1991-1997

* Vertical Integration ratio = (HYDRO + THERM) / (HV + LV)
Table 2. Degree of economies of scope, diversification and scale by electric utility (mean values 1991-1997).

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<tr>
<th>Vertical economies</th>
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<th>Scale economies</th>
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<td>$D^s (y^d_k, c^d_k)$</td>
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Table 3. The impact of alternative partitions on the operating costs of the Spanish electricity sector (percentage on total costs).

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