The Measurement of Scope, Scale and Diversification Economies: How Efficient is Electricity Restructuring and Unbundling?

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Background

Electricity liberalising reforms: break-up of public monopolies before privatisation and unbundling.

Break-up of monopolies to create a sufficient number of competitors in generation.

Vertical separation or unbundling:

i) To avoid discrimination in the competitive segments and therefore to limit the ability to distort competition

ii) To improve the effectiveness of regulation.

Background

- Insufficient restructuring: high concentration in generation and vertical integration obstacle competition.

- Structural policies to reduce market power of large private firms:

  - Divestiture of generating assets: Ofgen (1996, 1999)
  - European Merger Policy: EDF-EnBW (2001) Approval subject to 6,000 MW divestiture by EDF.
  - California: Financial incentives (higher allowed rate of return) to induce divestiture of 50% of the fossil-fuel generation assets owned by the largest utilities.

Background

Firms claim the existence of economies derived from:

- Technological interdependency between stages: vertical economies from stage coordination and the use of common inputs.
- Economies of horizontal integration: product mix economies from joint planning and operation.
- Scale economies derived from unit size.

Motivation of the Study

Any fragmentation faces a fundamental trade-off:

Potential efficiency gains due to market power mitigation

vs

Potential efficiency losses due to the waste of scale and scope economies

Objective

This paper estimates the degree of economies of scope, diversification and scale in the electricity industry by means of non-parametric frontier techniques.

We assess the impact that alternative firm partitions would have on the operating costs of the Spanish electricity sector.

Some preliminary results on horizontal and vertical economies from US data are also presented.

Earlier Studies on Scope and Scale Economies in the Electricity Industry

- Economies of Vertical Integration (Generation/Distribution)

USA: Kaserman & Mayo (1991): 12% (average firm)

Lee (1995): 4%

Gilsdorf (1994): no found

Hayashi *et al* (1997): 13-16%

Kwoka (2002): 13% - 57% (43% average firm)

Japan: Nemoto & Goto (2004): 0.13% - 2.97%

Spain: Jara *et al* (2004): 6.5% (average firm)

Earlier Studies on Scope Economies in the Electricity Industry

- Economies of Horizontal Integration: 9.2% (average firm) Jara *et al* (2004)

- Economies of scale -at firm level- exhausted for:

9000 Gwh (generation) 5000GWh (distribution) Kaserman&Mayo (1991)

8200 Gwh (generation) 11350 GWh -(distribution) Jara *et al* (2004)

Methodology

Previous studies: estimation of multistage-multioutput cost functions. For example: Translog cost function

$$\ln C(y, w) = a_0 + \sum_{i=1}^{m} a_i \ln y_i + \sum_{i=1}^{n} b_i \ln w_i$$

$$+ \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij} \ln y_i \ln y_j + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{n} b_{ij} \ln w_i \ln w_j$$

$$+ \sum_{i=1}^{m}\sum_{j=1}^{n} g_{ij} \ln y_i \ln w_j$$

Methodology: Non parametric frontier approach (DEA)

1. Cost frontier *vs* cost function.
2. It is not imposed a specific functional form to describe the production technology (e.g. quadratic, translog, etc.)
3. Specific benchmark frontiers are constructed for diversified and specialised utilities.

Multiproduct Cost Concepts

Scope Economies

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

When y_1 and y_2 are outputs corresponding to adjacent stages in the vertical chain (i.e. generation and distribution of electricity) reveals the existence of vertical (or multistage) scope economies

$$SC(y) = \frac{C(y_1) + C(y_2) - C(y_1, y_2)}{C(y_1, y_2)}$$

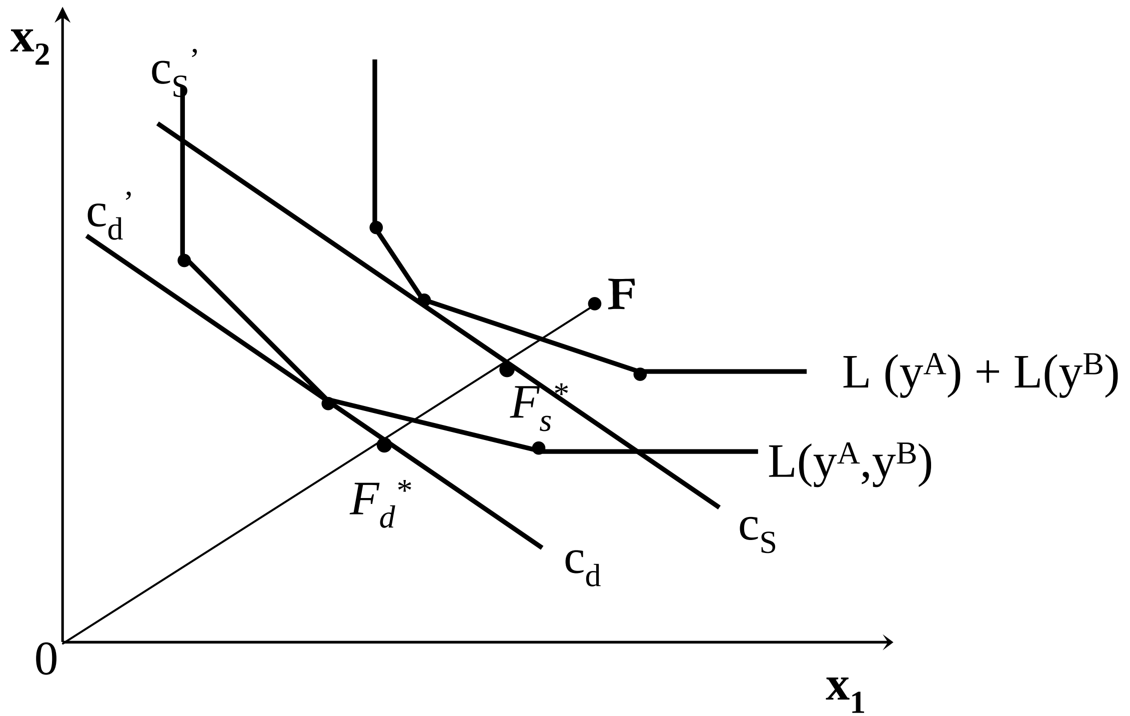
Multiproduct cost concepts

Horizontal Diversification Economies

$$C(y_1^A, 0, y_3^A) + C(0, y_2^B, y_3^B) > C(y_1^A, y_2^B, y_3^A + y_3^B)$$

$$DIV(y) = \frac{C(y_1^A, 0, y_3^A) + C(0, y_2^B, y_3^B) - C(y_1^A, y_2^B, y_3^A + y_3^B)}{C(y_1^A, y_2^B, y_3^A + y_3^B)}$$

Efficiency of joint production



$$\frac{OF_D^*}{OF} \Big/ \frac{OF_S^*}{OF} = \frac{C_D^*}{C_S^*}$$

The measurement of economic efficiency with D.E.A.

$$\min(y_k, w_k) = \min_{z,x} w_k \cdot x_k$$

$$s.a$$

$$\boldsymbol{Y}z \geq y_k$$

$$\boldsymbol{X}z \leq x_k$$

$$z \in R_+^K$$

$$\sum_{k=1}^{K} z_k = 1$$

The measurement of economic efficiency with D.E.A. when firms face same input prices

$$D^d\left(y_k^d, c_k^d\right) = \min_z \lambda$$

$$s.t$$

$$Y^d z \geq y_k^d$$

$$C^d z \leq \lambda c_k^d$$

$$z \in R_+^K$$

$$\sum_{k=1}^{K} z_k = 1$$

$$D^S\left(y_k^d, c_k^d\right) = \min_z \lambda$$

$$s.t$$

$$Y^S z \geq y_k^d$$

$$C^S z \leq \lambda c_k^d$$

$$z \in R_+^K$$

$$\sum_{k=1}^{K} z_k = 1$$

Data and variables

COST= Operating costs at constant 1990 prices = O&M costs from generation,distribution and supply + Depreciation and Amortization

OUTPUTS:

- HYDRO Net generation from hydro plants (MWh)
- THERM Net generation from thermal plants (MWh)
- LV Low voltage power (MWh)
- HV High voltage power (MWh)
- CUSTO Number of customers

Average values for Spanish power companies (1991-1997)

	COST	HYDRO	%	THERM	%	LV	%	HV	%	CUSTO	IVratio
HCantab	288263	720	9	7002	91	1288	21	4748	79	444809	128
UFenosa	921183	3559	18	16300	82	8584	41	12351	59	2340727	95
Iberdrola	1750724	13188	30	30982	70	27790	63	2647	49	7991148	81
Endesa	1289465	1486	4	37626	96	0	0	0	0	0	0
Sevillana	585596	1039	8	11149	92	9242	48	10195	52	3368529	63
Fecsa	414163	2036	18	9322	82	7825	53	6908	47	1828987	77
ERZ	88223	697	100	0	0	2046	47	2321	53	634754	16
ENHER	330989	2618	87	400	13	4501	46	5236	54	924965	31
GESA	132595	0	0	3090	100	2145	81	489	19	496757	117
Unelco	288919	0	0	4250	100	2663	68	1260	32	727823	108
Viesgo	101253	831	32	1730	68	1229	38	2003	62	447002	79
HEC	96246	613	100	0	0	2311	61	1487	39	538498	16
Average div. firm	695119	4067	24	13067	76	9343	47	10495	53	2610535	86

The Firms

Group 1 (generators):

ENDESA

Group 2 (distributors specialised in hydro generation)

ERZ, ENHER, HEC

Group 3 (distributors specialised in thermal generation)

SEVILLANA, GESA, UNELCO

Group 4 (diversified firms):

Iberdrola, U.Fenosa, H.Cantabrico, Viesgo, Fecsa

Combination A: Group 1+ Group 2 (49 composites)

Combination B: Group 2+ Group 3 (343 composites)

Results: vertical and horizontal economies

	Vertical economies			Diversification economies		
	$D^d(y_k^d, c_k^d)$	$D_A^S(y_k^d, c_k^d)$	$SC(y_k^d)$	$D^d(y_k^d, c_k^d)$	$D_B^S(y_k^d, c_k^d)$	$DIV(y_k^d)$
FECSA	0.957	1.003	0.049	0.957	0.962	0.005
HCANTÁBRICO	0.883	0.935	0.059	0.883	0.940	0.065
IBERDROLA	0.912	0.990	0.080	0.912	0.955	0.045
U.FENOSA	0.816	0.986	0.211	0.816	0.983	0.207
VIESGO	0.946	0.966	0.021	0.946	0.947	0.000

$$SC\left(y_k^d\right)=\frac{D_A^s\left(y_k^d,c_k^d\right)\cdot c_k^d-D^d\left(y_k^d,c_k^d\right)\cdot c_k^d}{D^d\left(y_k^d,c_k^d\right)\cdot c_k^d}=\frac{D_A^s\left(y_k^d,c_k^d\right)}{D^d\left(y_k^d,c_k^d\right)}-1$$

$$DIV\left(y_k^d\right)=\frac{D_B^S\left(y_k^d,c_k^d\right)\cdot c_k^d-D^d\left(y_k^d,c_k^d\right)\cdot c_k^d}{D^d\left(y_k^d,c_k^d\right)\cdot c_k^d}=\frac{D_B^S\left(y_k^d,c_k^d\right)\cdot c_k^d}{D^d\left(y_k^d,c_k^d\right)\cdot c_k^d}-1$$

Scope Economies: US sample

- 117 Investor Owned Utilities (1996)
- 54 Diversified and Vertically Integrated Utilities: SNHD (Steam, Nuclear, Hydro & Distribution)
- 20 Steam generators vertically integrated (SD)
- 43 Full Specialised Utilities:

    10 Steam generators (S)

    10 Hydro generators (H)

    6 Nuclear generators (N)

    17 Distributors (D)

Results for US utilities

- SD *vs* (S+D)

  Economies of Vertical Integration = 8.5%

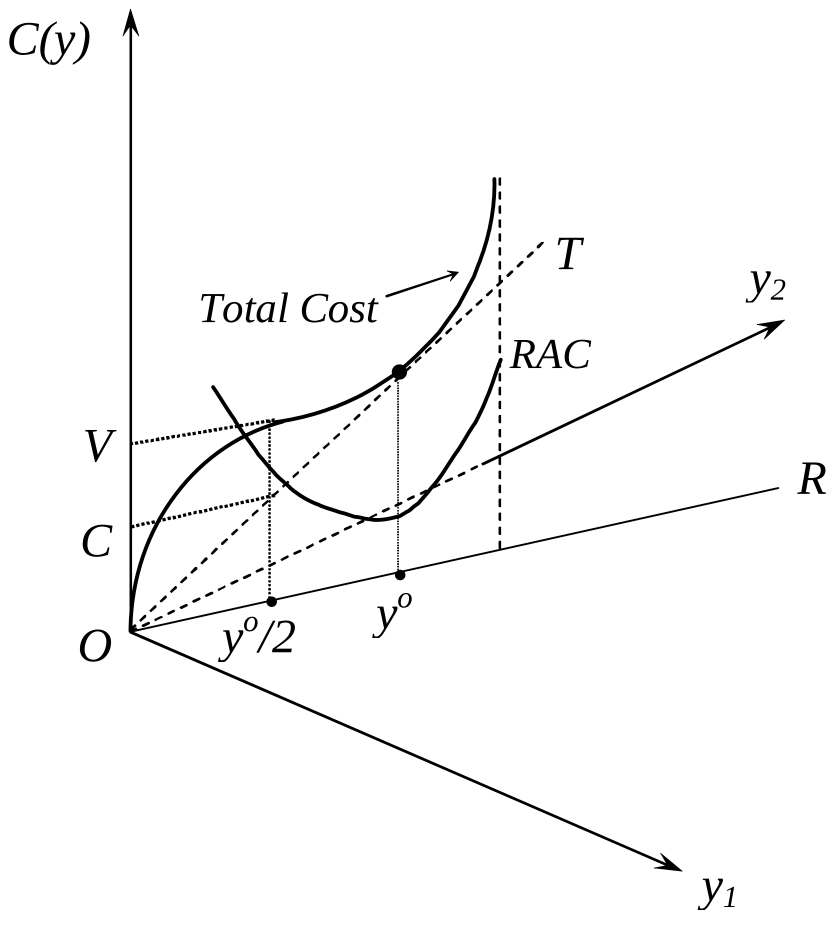
  (for the average SD firm)

- SNHD *vs* (S+N+H+D)

  Scope (vertical & horizontal economies) = 27.5%

  (for the average SNHD firm)

Ray Average Cost and Multiproduct Scale Efficiency



The measurement of scale efficiency

$$\varepsilon_d = \frac{D^{crs}\left(y^d, c^d\right)}{D^{vrs}\left(y^d, c^d\right)} \qquad \varepsilon_{d/2} = \frac{D^{crs}\left(y_d/2, c_d/2\right)}{D^{vrs}\left(y_d/2, c_d/2\right)}$$

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

The degree of scale economies

	Scale economies		
	ε_d	$\varepsilon_{d/2}$	$RSE(y_k^d)$
FECSA	0.999	1.000	-0.001
HIDRO. CANTÁBRICO	0.947	0.985	-0.039
IBERDROLA	0.941	1.000	-0.059
UNIÓN FENOSA	0.857	0.943	-0.092
VIESGO	0.991	0.992	-0.001

Average US diversified utility

RSE (SNHD) = -0.004

The impact of alternative partitions on the oprating costs of the Spanish electricity sector (% on total costs)

	$SC\,(y_k^d)$	$DIV\,(y_k^d)$	$RSE\,(y_k^d)$
1991	7.3	6.6	-1.3
1992	3.4	3.6	-5.9
1993	3.4	2.6	-4.5
1994	3.5	3.1	-0.7
1995	4.7	3.9	-4.5
1996	7.6	4.1	-0.4
1997	2.8	1.2	-2.3
Mean	4.7	3.5	-2.7

Conclusions

Our results suggest that structural policies aimed at creating a more fragmented and competitive electricity industry should take into account that:

(i) Vertical separation and horizontal specialisation on the generation stage may cause substantial efficiency losses, which should be compared with those gains expected from increasing competition.

(ii) A partition of large diversified firms in smaller units might have positive effects on economic efficiency because of the improvement of scale efficiency, provided that vertical and horizontal output proportions are preserved.