Cost Savings from Generation and Distribution with an Application to Italian Electric Utilities

Giovanni FRAQUELLI, Massimiliano PIACENZA, Davide VANNONI

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Fondazione Collegio Carlo Alberto
Via Real Collegio, 30
10024 - Moncalieri (TO)
Tel: 011 670 5250
Fax: 011 6705089
info@hermesricerche.it
http://www.hermesricerche.it

Cost Savings from Generation and Distribution with an Application to Italian Electric Utilities

GIOVANNI FRAQUELLI [a]
(*University of Eastern Piedmont and HERMES*)

MASSIMILIANO PIACENZA [b]
(*Ceris-CNR and HERMES*)

DAVIDE VANNONI [c]
(*University of Turin and HERMES* [d])

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Abstract

In the last decade a new regulatory framework for electric utilities, aiming at a gradual liberalization of the sector, has been set in Europe. The promotion of competition among generators implies the need to separate power generation from downstream transmission and distribution activities. However, if cost savings can be reached by operating at different stages, vertical separation is accompanied with a lost of efficiency. This paper investigates the latter issue by testing for the presence of economies from vertical integration on a sample of 25 Italian local electric utilities, observed in the years 1994-2000. The estimates of a *Composite Cost Function* model show for the average firm (300 million Kwhs of generation and 600 million Kwhs of distribution) that both multi-stage economies of scale and vertical economies are present. These measures increase with firm size, with the cost savings of vertical integration rising from 3% up to 40% for large operators. Furthermore, fully integrated utilities, for which the ratio of generated over distributed electricity is unity, enjoy higher cost synergies with respect to firms characterized by lower own-generation ratios. Overall, our findings suggest caution in pursuing a systematic breakdown of vertically integrated electric utilities.

Key words: Electric Utilities, Liberalization, Vertical Integration, Composite Cost Function

JEL: L11, L50, L94

[a] *Faculty of Economics, University of Eastern Piedmont "A. Avogadro", Via Perrone 18, 28100 Novara, Italy. Phone: +39-(0)11-5601210. E-mail: giovanni.fraquelli@eco.unipmn.it.*

[b] *Ceris-CNR, Institute for Economic Research on Firms and Growth, Italian National Research Council, Via Avogadro 8, 10121 Torino, Italy. Tel: +39-(0)11-5601241. Fax: +39-(0)11-5626058. E-mail: M.Piacenza@ceris.cnr.it.*

[c] *Faculty of Economics, University of Turin, Corso Unione Sovietica 218bis, 10134 Torino, Italy. Phone: +39-(0)11-6706083. E-mail: Vannoni@econ.unito.it*

[d] *HERMES, Center for Research on Regulated Services, Collegio Carlo Alberto, via Real Collegio 30, 10024 Moncalieri (TO), Italy.*

1. Introduction

In the last decade most industrialized countries have promoted liberalization processes in formerly monopolized network industries. In the European electricity industry, the guidelines of the new regulatory framework are essentially aimed at: a) separating power generation from downstream transmission and distribution activities (either in the form of ownership separation of in the weaker form of accounting separation, i.e. functional unbundling); b) opening the market (freedom of choice of the supplier); c) granting a free access to the network. This would help to create a real level playing field in which competing generation companies will bid into a power pool, transmission and distribution companies will provide access to all network users on non discriminatory terms, and the wholesale and retail supply market will be partially or fully open to competition.

The need to restructure an industry that, due to the natural monopoly argument, was historically dominated by privately or publicly owned vertically integrated incumbents, is due to different reasons. First, the advent of significant technology improvements and the progressive decline of natural gas prices jointly played to reduce the minimum efficient scale required for generating electric power. Second, prices were perceived to be too high due to market power conditions. Third, customers were dissatisfied about some aspects of the pricing behavior of incumbents, among which the practice to discriminate across customer classes. An appropriate mix of privatization, liberalization and regulation might be very effective in promoting competition in the electricity industry, leading to a reduction of end users prices, bringing an increase in the quality of the service, and securing long run supply.

However, the implementation of such reforms can also imply the lost of cost synergies that were coming from (or at least could have come from) the simultaneous presence of the same utility at backward and forward stages of the productive chain. In fact, due to the strict technological interdependency across stages, vertically integrated electric firms can exhibit lower average operations and maintenance costs as compared to utilities specialized in only one activity (generation, transmission and distribution). For example, some fixed costs, such as overhead expenses, have not to be duplicated and can be spread across stages. To take another example, a centralized decision center can be more effective in coordinating activities across stages (i.e. it can schedule the shutdowns for maintenance activities, or it can jointly decide the localization and the size of both new generating plants and transmission grids). A vertical structure can enjoy savings on transaction costs too, which are high in the presence of asset specific investments and market uncertainty. Finally, by internalizing the pricing decision of generated power, vertical integration allows to avoid the double marginalisation problem.

The above potential cost savings must be weighted against some well-known possible anti-competitive effects of vertical integration. In a regulated and partially liberalized market incumbents can in fact be left with substantial market power and distort competition in several ways. In the generation stage, they might limit the supply in order to keep prices high. In the transmission stage, they may charge discriminatory prices for the right to use the transmission grid. Cross-subsidization practices and predatory behavior are other dangers in the cases in which transmission, distribution and supply activities are run by the same company. Summarizing, vertical separation, far from being an end in itself, can be justified to the extent that the above market distortions outweigh the efficiency gains of vertical integration.

This paper contributes to the above debate by analyzing the cost function of a sample of 25 Italian local electric utilities observed during a seven-year period (1994-2000). By using a multiproduct cost function, we are able to obtain estimates of aggregate returns to scale and to detect the presence of cost efficiencies of vertical integration strategies. From a methodological perspective, we recur to the *Composite Cost Function* specification, which has been originally introduced by Pulley and Braunstein (1992) to measure scope economies in the banking industry. By combining the log-quadratic input price structure of the well-known Translog and Generalised Translog (or Box-Cox) models with a quadratic structure for multiple outputs, such a functional form is well suited for empirical cost analysis.

The rest of the paper is organized as follows. In section 2 we briefly review the empirical literature addressing the issue of vertical economies in the electricity industry. In section 3 we present the composite cost function model used in the analysis. In section 4 we describe our dataset and show the main results of our estimates. In section 5 we conclude.

2. The empirical literature on vertical economies

Polo and Scarpa (2003) maintain that “the theoretical debate over the desirability of vertical integration is not very developed, in that the few contributions on the subject acknowledge that while there may be some reasons why integration leads to greater efficiency, the development of competition is helped by separation. Therefore the relative desirability of integration is ultimately an empirical matter, and should be based on a careful account of the actual advantages and disadvantages of the two solutions"(p.3).

On the empirical side, Kaserman and Mayo (1991) were the first to adapt the concept of multiproduct economies of scope to analyze the cost advantages of vertical integration. They estimated a multistage quadratic cost function on a cross section of 74 US firms for year 1981, and provided evidence of vertical economies for firms that generated and distributed more than 6 million Mwhs of electricity. Moreover, the cost savings with respect to specialized utilities (i.e. the difference between the sum of the costs of pure generators and pure distributors and the costs of integrated firms) were found to increase with the size of the utility, and ranged from a minimum of 3% (in the case of a fully integrated firm that generated and distributed 8 million Mwhs) to a maximum of 90% (for a fully integrated firm that generated and distributed 18 million Mwhs). Another results was that stage specific economies of scale were exhausted at relatively low output levels for both generation and distribution, so that the estimates for multistage economies of scale were much lower than the estimates of vertical economies (for a fully integrated firm that generated and distributed 18 million Mwhs the measure of aggregate scale economies was 1.14).

Subsequent works extended under several respects the above seminal contribution. A first problem was that Kaserman and Mayo (1991) did not net out purchased power expenses from total accounting costs, and had to recur to an *ad hoc* adjustment of the formula for computing vertical economies in order to avoid a double imputation of such expenses. Moreover, their quadratic functional form has been criticised in that "it assumes marginal costs are independent of input prices and other hedonic characteristics. In addition, no mention is made regarding satisfaction of the linear homogeneity requirement of a well-behaved cost function" (Gilsdorf, 1994, p.264).

The empirical strategy followed by Gilsdorf (1994) and Piacenza and Beccio (2004) is the joint estimation of a Translog cost function with the corresponding input cost share equations using Zellner's (1962) iterative SUR procedure. Such a specification is consistent with duality theory and allows to impose the homogeneity restrictions, but cannot be used to obtain direct measures of economies of scope. An indirect way to overcome the above limit and obtain insights on vertical synergies is to conduct cost complementarity tests.[1] The results they got are far from being conclusive, since Gilsdorf (1994) found evidence against cost complementarity on a sample of 72 fully integrated (i.e engaged in production, transmission and distribution) US electric utilities for the year 1985, while Piacenza and Beccio (2004) provided evidence in favor of cost complementarity on a sample of 14 fully integrated Italian electric utilities observed for the period 1994-2000.

Kwoka (2002), using a quadratic cost function for a sample of 147 U.S. electric utilities observed in 1989, found evidence of vertical economies ranging from 3% (for a fully integrated utility generating and distributing 5 million Mwhs) to 73% (50 million Mwhs of generation-distribution). Even if the specification includes input prices among the regressors, and purchased power is correctly subtracted from operating costs, the quadratic model proposed by Kwoka (2002) is fairly *ad hoc*: the linear homogeneity restrictions are not imposed, and input cost-share equations are not estimated together with the cost function. Moreover, as in Kaserman and Mayo (1991), standard deviations of the estimates of scale and vertical economies are not provided, so it is not clear in which cases the figures can be considered as statistically different from one and zero, respectively.

Curiously enough, both Gilsdorf (1994, p.277-278) and Kwoka (2002, p. 659), while following different empirical strategies, underline the advantages of the *Composite Cost Function* introduced by Pulley and Braunstein (1992). Such a specification encompasses both translog-type and quadratic-type models, is consistent with duality theory, and well suited to provide precise measures of scale and vertical economies. The empirical analysis in this paper is based on such a functional form, so that our results can be directly compared with the ones obtained by the above cited papers.

However, a rather different approach to the study of vertical economies recently appeared in the literature. The underlying idea is that, instead of relying on the estimation of the cost function as a whole, one can specify the cost function of each stage, and test for the presence of technological externalities between stages. For example, Hayashi et *al.* (1997) tested on a sample of 55 US electric utilities over the 1983 to 1987 period if the generation and distribution stages were separated or

[1] Pair-wise cost complementarity occurs when the marginal cost of producing output at stage *i* decreases as the output produced at stage *j* increases ($\partial^2 c/\partial y_i \partial y_j < 0$) and is a sufficient condition for the existence of economies of scope.

interconnected. The results of the separability tests[2] pointed to the rejection of the separability hypothesis, suggesting that an integrated firm can reduce total costs of electric supply. Nemoto and Goto (2004) checked on a sample of 9 Japanese electric utilities over the period 1981-1998 whether the costs of transmitting-distributing electricity were affected by the level of capital stock at the generation stage. The results showed a positive effect of generation capital on downstream costs. As more generation plants join the network, the higher are the transmission-distribution costs, which implies that an integrated structure would be able to enjoy cost savings by internalizing such negative externality. Moreover, the authors found evidence of the presence of allocative distortions, in that electric utility firms tended to over-utilize capital and under-utilize electricity input relative to labor. This result is clearly against cost minimization, which is an almost universally accepted hypothesis in this field of studies.[3] The above contributions are interesting and certainly rise important questions. However, to undertake this sort of empirical analysis, one should be able to construct a very rich dataset with highly detailed information about costs, outputs and input prices at each productive stage, which is far beyond our present possibilities.

3. A composite model for analyzing vertical economies

The availability of data on costs and on generated and distributed electricity allows us to undertake a detailed study of the cost function of Italian electric utilities, and to test if the latter can benefit from multistage economies and/or from economies of vertical integration.

As discussed in the previous section, most empirical works relied on the Translog specification or on variants of the quadratic model. Due to its log-additive output structure, the former suffers from the well-known inability to evaluate cost behavior when any output is zero. This has proved to yield unreasonable and/or very unstable values of the estimates for scope economies and product-specific scale economies. Moreover, quadratic models, even in more sophisticated specifications which satisfy homogeneity, symmetry and the other regularity conditions (such as the

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[2] The separability test consists in checking if the capital-labor ratio of the transmission-distribution activity is independent of the price of generated electricity, i.e. if the optimal choice of labor and capital in the downstream stage is independent of the price of the input obtained from the upstream stage.

[3] For example, Gilsdorf (1994, p. 269) maintains that: "Two important assumptions underlie direct estimation of a cost function: (1) exogenous output levels and input prices and (2) cost minimizing behavior. Electric utilities are required by regulators to meet all demand at regulated rates. Thus, output

CES-Quadratic proposed by Röller, 1990), require to impose strong separability between outputs and inputs prices, which appears to be a too much restrictive assumption.

The composite specification used in this analysis allows to overcome all of the above problems, so that it is particularly apt to detect the presence of aggregate and stage specific economies of scale and economies of vertical integration. Due to its log-quadratic input price structure, it can be easily constrained to be linearly homogeneous, while the quadratic structure for multiple outputs is appropriate to model cost behavior in the range of zero output levels.[4] The composite cost function is written as:

$$c=[\alpha_0+\sum_i \alpha_i y_i+\frac{1}{2}\sum_i\sum_j \alpha_{ij} y_i y_j+\sum_i\sum_r \delta_{ir} y_i \ln w_r]* \exp(\sum_r \beta_r \ln w_r+\frac{1}{2}\sum_r\sum_l \beta_{rl}\ln w_r \ln w_l) \qquad [1]$$

The associated input cost-share equations are obtained by applying the *Shephard's Lemma* to expression [1][5]

$$S_r=\left(\sum_i \delta_{ir} y_i\right)\left[\alpha_0+\sum_i \alpha_i y_i+\frac{1}{2}\sum_i\sum_j \alpha_{ij} y_i y_j+\sum_i\sum_r \delta_{ir} y_i \ln w_r\right]^{-1}+\beta_r+\sum_l \beta_{rl}\ln w_l \qquad [2]$$

c refers to the long-run cost of production, y_i and y_j refer to output at stages i and j, w_r and w_l indicate factor prices. The homogeneity restrictions are $\Sigma_r\beta_r = 1$, $\Sigma_l\beta_{rl} = 0$ for all r and $\Sigma_r\delta_{ir} = 0$ for all i, while symmetry requires $\alpha_{ij} = \alpha_{ji}$ and $\beta_{rl} = \beta_{lr}$.[6] Given the above regularity conditions ensuring duality, the composite specification is a flexible form which does not impose a priori restrictions on the characteristics of the below technology.

Assume the expression for multi-product cost function [1] to be summarized by $c = c(y; w)$, where y represents the vector of outputs and w the vector of input prices.[7] Following Baumol et *al.* (1982), local measures of scope economies and of global and

levels are exogenous to the firm. Competitive input markets are commonly assumed in the empirical literature and this assumption will be maintained here".

[4] For a discussion of the merits of such specification as compared to alternative functional forms, see Pulley and Braunstein (1992) , Fraquelli et *al.* (2002), and Piacenza and Vannoni (2004).

[5] Cost-shares are computed as $S_r = (x_r w_r)/c$, where x_r is the input demand for the rth input. By Shephard's Lemma $x_r = \partial c/\partial w_r$, so that $S_r = \partial \ln c/\partial \ln w_r$.

[6] Moreover, cost minimization requires the satisfaction of the following conditions: *a*) non-negative fitted costs; *b*) non-negative fitted marginal costs with respect to outputs; *c*) non-decreasing fitted costs in input prices; *d*) concavity of the cost function in input prices. Symmetry and linear homogeneity in input prices are imposed *a priori* during estimation, whilst the other regularity conditions are checked ex-post.

[7] In our two-output (stages), two inputs case: $y=(y_G, y_D)$ and $w=(w_L, w_O)$.

stage specific scale economies can be easily defined. *Global* or *multi-stage scale economies* are computed via

$$SE(y;w) = \frac{c(y;w)}{\sum_i y_i MC_i} = \frac{1}{\sum_i \varepsilon_{cy_i}} \qquad [3]$$

where $MC_i = \partial c(y;w)/\partial y_i$ is the marginal cost and $\varepsilon_{cy_i} = \partial \ln c(y;w)/\partial \ln y_i$ is the cost elasticity with respect to the output of the *i*th stage.

The above measure describes the behavior of costs as outputs at all stages increase by strictly the same proportion. However, since product mixes rarely remain constant as output changes, additional dimensions of scale behavior can be measured by stage-specific scale economies indicators. These latter show how costs change as the output of one stage changes, keeping constant the outputs produced in the other stages. *Stage-specific economies of scale* for the *i*th stage are defined by

$$SE_i(y;w) = \frac{IC_i}{y_i MC_i} = \frac{IC_i}{\varepsilon_{cy_i} c(y;w)} \qquad [4]$$

where $IC_i = c(y;w) - c(y_{-i};w)$ is the incremental cost relating to the output of the *i*th stage and $c(y_{-i};w)$ is the cost of producing at all other stages. Returns to scale are said to be increasing, constant or decreasing as $SE(y;w)$ and $SE_i(y;w)$ are greater than, equal to, or less than unity, respectively.

The second relevant concept in understanding the cost structure of multi-product firms is that of scope economies, here to be interpreted as vertical economies. The latter appear when the cost of producing at all stages is less than the sum of the "stand-alone" production costs at each stage. The measure of *vertical economies* for our two-stage case can be computed via

$$VE(y;w) = \frac{\left[c(y_G,0;w) + c(0,y_D;w) - c(y;w)\right]}{c(y;w)} \qquad [5]$$

with $VE(y;w)>0$ (<0) denoting vertical economies (diseconomies)[8].

[8] Note that equation [5] is a correct measure of vertical economies provided that purchased power expenses are netted out from distribution costs.

It can be helpful to report a relationship which summarizes the links between scale and vertical economies:

$$SE(y;w) = \frac{\sum_i \gamma_i SE_i(y;w)}{1 - VE(y;w)} \qquad [6]$$

where $\gamma_i = \frac{\varepsilon_{cy_i}}{\sum_i \varepsilon_{cy_i}}$. According to equation [6], the degree of multistage scale economies depends on both stage-specific scale economies and vertical economies. In particular, if $VE > 0$ ($VE < 0$), SE is greater (lower) than the weighted average of stage-specific scale economies SE_i.

4. Data, estimation and empirical results

4.1. Description of the dataset

Our dataset refers to a balanced panel of 25 Italian municipal electric utilities observed over the period 1994-2000, for a total of 175 *pooled* observations. 11 firms are pure distributors while 14 firms are integrated electric utilities.

Data on costs, output quantities and input prices are obtained by integrating the information available in the annual reports of each company with additional information drawn from questionnaires sent to managers. Total costs (c) are the sum of labor costs and of the costs of other inputs, which is a residual category that includes depreciation, maintenance, materials and services, but excludes the costs of purchased power. As already pointed out, such latter costs represent a simple transfer from the producer to the consumer, and they do not reflect "any productive activity by the purchasing utility in and of itself" (Gilsdorf, 1994, p.279). All monetary variables are expressed at constant prices at year 2000. The two output categories are kilowatt hours of generation (y_G) and kilowatt hours of distribution (y_D). Productive factors are labor (L) and other inputs (O). The price of labor (w_L) is given by the ratio of total salary expenses to the number of employees. The price of other inputs (w_O) is obtained by dividing residual expenses by the sum of generated and distributed electricity.[9]

[9] Our sample includes integrated operators and pure distributors, but detailed information on the value of fixed assets at the different stages, which is crucial in order to obtain acceptable proxies for the price of capital, is lacking. By including capital as a separate input and by dividing the user cost of capital by the length of the network, one would have ended up with an unjustified overestimation of the price of capital for vertically integrated firms as compared to pure distributors. The use of a residual category for all inputs different from labor, whose price (w_O) is obtained dividing the relative cost by the sum of generated

4.2. Estimation and empirical results

The multi-product cost function is estimated jointly with its associated input cost-share equations.[10] Before the estimation, all variables are standardized on their respective sample average values. Parameter estimates are obtained via a non-linear GLS estimation (NLSUR), which is the non-linear counterpart of the Zellner's iterated seemingly unrelated regression technique. This procedure ensures estimated coefficients to be invariant with respect to the omitted share equation (Zellner, 1962).

The results of the NLSUR estimations are presented in table 2.[11] Most of the coefficients are statistically different from zero at 1% level, and the summary statistics show that the estimated model performs quite well: the R^2 for the cost function and for the labor share equation are 0.997 and 0.615, respectively. McElroy's (1977) R_*^2, which is as a measure of the goodness of fit for the NLSUR system, is quite high as well. Finally, the last two rows of table 2 indicate that the model exhibits a good degree of satisfaction of the output and input price regularity conditions (98% and 94% of sample points, respectively).

Due to the flexibility of the functional form, the estimates of cost elasticities, input price elasticities, scale and vertical economies are not constant but vary with the size of explanatory variables. If we let outputs free to fluctuate but keep factor prices at their average values, ε_{cy_i}, S_r and SE are computed as follows:

$$\varepsilon_{cy_i} = \frac{\alpha_i + \sum_j \alpha_{ij}\lambda_j}{\alpha_0 + \sum_i \alpha_i\lambda_i + \frac{1}{2}\sum_i\sum_j \alpha_{ij}\lambda_i\lambda_j} \qquad [7]$$

$$S_r = \beta_r + \frac{\sum_i \delta_{ir}\lambda_i}{\alpha_0 + \sum_i \alpha_i\lambda_i + \frac{1}{2}\sum_i\sum_j \alpha_{ij}\lambda_i\lambda_j} \qquad [8]$$

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and distributed electricity, is the best we can do, given the existing information, to take into account the fact that outputs at the generation stage can be zero or positive.

[10] The two share equations sum to unity, so only one of them (the labor equation S_L) was included to avoid singularity of the covariance matrix.

[11] The software used for the estimation is LIMDEP Version 7.

$$SE = \frac{\alpha_0 + \sum_i \alpha_i \lambda_i + \frac{1}{2}\sum_i \sum_j \alpha_{ij}\lambda_i \lambda_j}{\sum_i \alpha_i \lambda_i + \sum_i \sum_j \alpha_{ij}\lambda_i \lambda_j} \qquad [9]$$

where coefficients $\lambda_i = y_i / \bar{y}_i$ and $\lambda_j = y_j / \bar{y}_j$ indicate expansions (if greater than one) and contractions (if lower than one) of the average outputs $\bar{y}_i$ and $\bar{y}_j$ observed in the sample. The results show for the average firm (for which $\lambda_i = \lambda_j = 1$)[12] that the estimated labor price elasticity $S_L = 0.39$, with a standard error of 0.007)[13] is close to the observed average value (see table 1), while output elasticities are 0.29 (s.e. = 0.018) for generation and 0.70 (s.e. = 0.017) for distribution. As a result of this, *SE* is equal to 1.015 (s.e. = 0.007) for the average firm, that reflects statistically significant weak increasing multistage returns to scale. Stage specific economies of scale are respectively $SE_G = 0.940$ (s.e. = 0.008) and $SE_D = 0.999$ (s.e. = 0.006), suggesting that the average firms is characterized by decreasing returns for the generation phase and constant returns for distribution. Finally, there is evidence of the presence of vertical economies, since $VE = 0.032$ (s.e. = 0.008). Table 3 presents in *Panel A* the estimates of multi-stage scale and vertical economies when the scale of operation of the average firm $y = \bar{y} = (\bar{y}_G , \bar{y}_D)$ is increased and reduced proportionally. The results show that firms at ray contractions of $\bar{y}$ ($\lambda \bar{y} = (\lambda \bar{y}_G , \lambda \bar{y}_D)$, with $\lambda<1$) exhibit decreasing but not statistically significant returns to scale, while firms at ray expansions of $\bar{y}$ ($\lambda \bar{y} = (\lambda \bar{y}_G , \lambda \bar{y}_D)$, with $\lambda>1$) are characterized by increasing and statistically significant returns to scale (for $\lambda = 8$, $SE = 1.37$). In a similar vein, the estimates for *VE* suggest the presence of vertical economies for firms bigger than the average. In fact, if $\lambda<1$, *VE* takes on negative but not statistically significant values, while for larger utilities it is greater than zero and statistically significant, with values that increase with firm size (vertical economies increase from 3% up to 44% in correspondence of $\lambda = 8$).

[12] The *average* firm (the point of normalization) corresponds thus to an hypothetical firm generating and distributing $\bar{y}_G$ and $\bar{y}_D$, and facing mean input price values.

[13] Standard errors for functions of least squares estimators, such as input cost shares, output elasticities, and measures of scale and scope economies, are computed through the Delta method, which exploits the estimated variance-covariance matrix of coefficients (Greene, 1997, pp. 278-280).

However, table 1 shows that, by generating about 300 million kwh and by distributing about 600 million kwh, the average electric utility in our sample is not representative of a fully integrated firm. In order to explore the cost advantages associated with full integration, *Panel B* of table 3 presents the estimates for aggregate scale and scope economies for firms endowed with a 100% own-generation ratio. The latter may be thought as utilities with output rays $y = \lambda' \bar{y} = (\lambda_G \ \bar{y}_G \ , \lambda_D \bar{y}_D \ )$, with $\lambda_G = 2\lambda_D$. The results clearly show that utilities can enjoy greater cost savings by increasing the generation ratio. For example, firms that generate and distribute 2.4 million Mwh exploit vertical economies of the order of 29%, which are greater than the cost savings (19%) attainable when the generation activity is enough to cover only 50% of the distribution needs (i.e. if $y_G = 1.2$ million Mwh).

Table 4 shows the estimates of vertical economies for different combinations of generation and distribution, with both λ_G and λ_D ranging between 1/8 and 8. The figures in the principal diagonal (bold characters) refer to output combinations corresponding to ray expansions and contractions of the outputs of the average firm $\lambda \bar{y}$, while the figures in the diagonal immediately below (in italics) refer to the output combinations which characterize a fully integrated firm $\lambda' \bar{y}$. As it is clearly reported in table 4 and in the corresponding figure 1, most output combinations where both y_G and y_D are below the average are associated with vertical diseconomies (even if the reported figures are not statistically different from zero), while vertical synergies are present at all output combinations where $y_G \geq 304$ and/or $y_D \geq 596$.

Table 5 shows the estimated costs for different combinations of generated and distributed electricity. Moving along the first column (first row) one can observe that there are decreasing returns to scale in generation (distribution). However, the hypothesis of constant stage-specific returns to scale for distribution ($SE_D = 1$) cannot be rejected at all output levels, so that we can broadly consider the distribution phase as an activity characterized by constant average costs. The figures in table 5 can be used to discuss the impact of different vertical structures on the costs of electric utilities. For example, AGSM Verona in 1998 was generating 671.7 million Kwh and distributing 628.2 million Kwh, with actual total costs of 87.593 million Italian lira. Vertical integration gains for such a utility are estimated at 6.5%. Table 5 shows that if a firm of a similar but slightly smaller size (producing respectively $y_G = 609$ and $y_D = 596$) was forced to separate generation from distribution, it would be replaced by two specialized utilities bearing on aggregate total costs of 89.848 million Italian lira.

Expression [6] is useful to summarize the relationship between multi-stage scale economies, on the one hand, and economies o vertical integration and stage-specific scale economies, on the other hand. Our results show that the overall increasing returns to scale found for large utilities are essentially due to the presence of vertical economies. In fact, the latter are so high as to counterbalance the effects of decreasing returns to scale in the generation phase. Thus, by operating simultaneously at both stages, firms may overcome the above limits to growth.

4.3. Robustness

In this section we test the robustness of our results by including in equations [1] and [2] a time trend t, a variable accounting for density effects (DEN = number of users per kilometer of distribution network), and three dummies, D_{LARGE}, D_{MEDIUM}, D_{SMALL}, which account for time-invariant size-group effects (i.e. large, medium, and small operators, respectively).

The last two columns in table 2 (EXTENDED MODEL) show that the coefficients are overall pretty much stable. Moreover, there has been a slight reduction of production costs due to favorable technological change during the 1994-2000 period (γ_t = -0.012), while the negative sign of γ_{DEN} implies that a higher user density puts a downward pressure on the costs of electric utilities. By applying the appropriate intercept, γ_{LARGE}, γ_{MEDIUM}, γ_{SMALL}, to utilities belonging to different size-classes, we obtain estimates for vertical economies which are rather similar to the ones shown in tables 3 and 4. For example, for small firms ($\lambda_G = \lambda_D = 0.25$) VE is equal to -0.04 (s.e. = -0.857), for medium firms ($\lambda_G = \lambda_D = 1$) it is equal to 0.03 (s.e. = 0.013), while it reaches 0.05 (s.e. = 0.022) and 0.40 (s.e. = 0.065) for larger utilities ($\lambda_G = \lambda_D = 2$ and 8, respectively). Therefore, we can be reasonably confident that the results presented in the previous section are not affected by the presence of time, size-group, and density effects.

5. Conclusions

In recent years changes of regulation in European electricity industry have been oriented towards a gradual liberalization of the sector, which implies also the need to separate generation from distribution in order to promote competition among generators. The systematic breakdown of a structure that was traditionally dominated by large vertically integrated utilities cannot be an optimal policy if substantial economies of vertical integration are at place. In this study we use a unique dataset which includes 25 Italian local electric utilities (of which 14 are operating in both generation and distribution and 11 are pure distributors) observed during the period 1994-2000, in order to investigate the cost efficiencies of vertical integration strategies.

From a methodological point of view, we use the multiproduct *Composite Cost Function,* which combines the log-quadratic input price structure of the well-known Translog and Generalised Translog (or Box-Cox) models with a quadratic structure for multiple outputs. Such a specification has been originally introduced by Pulley and Braunstein (1992) and has repeatedly proved to be particularly suitable for empirical cost analysis, especially in the presence of zero output levels.

This paper allows to confirm and to refine the preliminary findings obtained by Piacenza and Beccio (2004) for Italy, while extends the results obtained by Kaserman and Mayo (1991) and Kwoka (2002) for the United States. Piacenza and Beccio (2004) tested a Translog Cost Model on a sub-sample of 14 integrated electric utilities, and found widespread cost complementarities between the upstream and downstream stages, but were unable to obtain a measure of such cost synergies. This paper uses an extended dataset which includes also 11 single-product (distribution) utilities and relies on a more rigorous methodology which allows to measure with precision the extent of economies of vertical integration for different combinations of generated and distributed electricity.

The results highlight for the average firm (which generates about 300 million Kwhs and distributes about 600 million Kwhs of electricity) the presence of weak but statistically significant economies of vertical integration (3%) as well as of multi-stage scale economies (1.015). Firms which are smaller than the average exhibit negative but not statistically significant vertical economies, which are associated with non statistically significant decreasing returns to scale. More interestingly, utilities which generate and distribute more than the average firm benefit from both economies of vertical integration and increasing returns to scale, and the cost advantages increase up to 40% for large operators (2.5 million Mwhs of generation and 5 million Mwhs of distribution). Finally, fully integrated firms (that is utilities for which the ratio of generated electricity over distributed electricity is unity) enjoy higher cost synergies with respect to utilities characterized with lower own-generation ratios. As compared to Kaserman and Mayo (1991) and Kwoka (2002), who found vertical diseconomies for firms generating and distributing less than 5-6 million Mwhs, our findings point to the presence of substantial vertical economies in a much wider output region, highlighting that also small-sized firms, such as the local electric utilities in our sample, could enjoy important cost savings by resorting to vertical integration strategies.

From a regulatory policy point of view, this evidence suggests that the breakdown of vertically integrated firms, implied by the ongoing liberalization of the electricity industry, has to be pursued with caution. In particular, the introduction of competition among generators should be accompanied with new organizational structures (such as, for instance, pools among generation and distribution firms), which allow operators to recover the efficiency previously associated with the simultaneous presence at upstream and downstream production stages.

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Table 1. Summary statistics

VARIABLES		*Mean*	*standard dev.*	*min*	*max*
c	Total costs (10^6 Italian lire)	66,169	124,592	1007	496,644
Y_G	Generation (10^6 Kwh)	304.26	694.19	0	3411.50
Y_D	Distribution (10^6 Kwh)	596.11	1073.81	13.20	4900.00
w_L	Price of labor (10^6 lire Italian lire)	84.78	11.29	66.78	118.05
w_O	Price of other inputs (10^6 Italian lire)	40.62	13.91	11.07	84.53
S_L	Labor cost-share	0.42	0.13	0.15	0.82
S_O	Other input cost-share	0.58	0.13	0.18	0.85
DEN	User density	58	37	13	202

Table 2. NLSUR estimates for parameters of the *composite* cost function [1]

REGRESSORS [a]	PARAMETERS	BASIC MODEL estimates	BASIC MODEL s.e.	EXTENDED MODEL estimates	EXTENDED MODEL s.e.
Constant	α_0	-0.013*	(0.007)	-	-
Y_G	α_G	0.292***	(0.018)	0.235***	(0.015)
Y_D	α_D	0.731***	(0.029)	0.782***	(0.034)
Y_G^2	α_{GG}	0.034***	(0.004)	0.031***	(0.005)
Y_D^2	α_{DD}	0.001	(0.008)	-0.023***	(0.008)
$Y_G Y_D$	α_{GD}	-0.045***	(0.005)	-0.036***	(0.006)
$\ln w_L$	β_L	0.404***	(0.042)	0.440***	(0.008)
$\ln w_O$	β_O	0.596***	(0.042)	0.560***	(0.008)
$\ln w_L^2$	β_{LL}	0.203***	(0.012)	0.224***	(0.011)
$\ln w_O^2$	β_{OO}	0.203***	(0.012)	0.224***	(0.011)
$\ln w_L \ln w_O$	β_{LO}	-0.203***	(0.012)	-0.224***	(0.011)
$Y_G \ln w_L$	δ_{GL}	-0.053***	(0.012)	-0.051***	(0.006)
$Y_D \ln w_L$	δ_{DL}	0.037	(0.030)	0.006	(0.004)
$Y_G \ln w_O$	δ_{GO}	0.053***	(0.012)	0.051***	(0.006)
$Y_D \ln w_O$	δ_{DO}	-0.037	(0.030)	-0.006	(0.004)
t	γ_t	-	-	-0.012***	(0.002)
DEN	γ_{DEN}	-	-	-0.020*	(0.012)
D_{LARGE}	γ_{LARGE}	-	-	0.365***	(0.069)
D_{MEDIUM}	γ_{MEDIUM}	-	-	0.002	(0.033)
D_{SMALL}	γ_{SMALL}	-	-	0.038***	(0.014)
McElroy's R_*^2		0.996 [b]		0.997 [b]	
Cost function R^2		0.997		0.998	
Labor-share equation R^2		0.615		0.585	
Regularity conditions:					
- output regularity satisfaction		98%		94%	
- price regularity satisfaction		94%		78%	

[a] The coefficient subscripts are G = generation, D = distribution, L = labor input, O = other inputs, t = time trend, *DEN* = user density, *LARGE* = large firms, *MEDIUM* = medium firms, *SMALL* = small firms.
[b] The goodness-of-fit measure for the NLSUR systems is McElroy's (1977) R_*^2.

*** Significant at 1 percent level in a two-tailed test.

* Significant at 10 percent level in a two-tailed test.

Table 3. Estimates of multi-stage economies of scale (*SE*) and economies of vertical integration (*VE*) by scaled values of the average outputs (at the average input prices) for partially and fully integrated firms [a]

Panel A: Partially integrated firms			*Panel B: Fully integrated firms*		
Scaling procedure:	*SE*	*VE*	Scaling procedure:	*SE*	*VE*
$\lambda_G = \lambda_D = 0.125$	0.902 (0.098)	-0.110 (0.071)	$\lambda_G = 0.25$ $\lambda_D = 0.125$	0.923 (0.044)	-0.080 (0.052)
$\lambda_G = \lambda_D = 0.25$	0.956 (0.029)	-0.040 (0.031)	$\lambda_G = 0.5$ $\lambda_D = 0.25$	0.964 (0.021)	-0.020 (0.024)
$\lambda_G = \lambda_D = 0.5$	0.988 (0.014)	0.000 (0.015)	$\lambda_G = 1$ $\lambda_D = 0.5$	0.988 (0.011)	0.015 (0.012)
$\lambda_G = \lambda_D = 1$	1.015 (0.007)	0.032 (0.008)	$\lambda_G = 2$ $\lambda_D = 1$	1.010 (0.005)	0.059 (0.009)
$\lambda_G = \lambda_D = 2$	1.052 (0.006)	0.086 (0.011)	$\lambda_G = 4$ $\lambda_D = 2$	1.029 (0.004)	0.136 (0.016)
$\lambda_G = \lambda_D = 4$	1.130 (0.012)	0.192 (0.024)	$\lambda_G = 8$ $\lambda_D = 4$	1.070 (0.009)	0.288 (0.034)
$\lambda_G = \lambda_D = 8$	1.365 (0.005)	0.441 (0.057)			

[a] Estimated standard errors in parentheses. Parameters λ_G and λ_D refer to the coefficients used to scale down (λ_i = 0.125, 0.25, 0.5) and up (λ_i = 2, 4, 8) the average values of generation and distribution outputs (λ_i = 1), respectively.

Table 4. Estimated vertical economies for different combinations of generation (Y_G) and distribution (Y_D) [a]

	Y_D (10^6 Kwh):						
	75 [λ_D = 0.125]	149 [λ_D = 0.25]	298 [λ_D = 0.5]	596 [average value]	1,192 [λ_D = 2]	2,384 [λ_D = 4]	4,769 [λ_D = 8]
Y_G (10^6 Kwh):							
38 [λ_G = 0.125]	**-0.11**	-0.06	-0.03	-0.01	0.00	0.00	0.01
76 [λ_G = 0.25]	*-0.08*	**-0.04**	-0.02	0.00	0.01	0.01	0.01
152 [λ_G = 0.5]	-0.04	*-0.02*	**0.00**	0.01	0.02	0.03	0.03
304 [average value]	-0.02	0.00	*0.01*	**0.03**	0.05	0.05	0.06
609 [λ_G = 2]	0.00	0.01	0.03	*0.06*	**0.09**	0.11	0.12
1,217 [λ_G = 4]	0.01	0.02	0.04	0.08	*0.14*	**0.19**	0.24
2,434 [λ_G = 8]	0.01	0.02	0.05	0.09	0.17	*0.29*	**0.44**

[a] The figures in bold characters refer to output combinations corresponding to ray contractions and ray expansions of the average production ($Y_G = 304$, $Y_D = 596$), whilst the figures in italics refer to output combinations corresponding to fully integrated firms.

Table 5. Estimated costs (10^6 Italian lire) for different combinations of Y_G and Y_D [a]

	Y_D (10^6 Kwh):						
	0	75	149	298	596	1,192	2,384
Y_G (10^6 Kwh):							
0	*0*	*5,193*	*11,241*	*23,339*	*47,549*	*96,021*	*193,176*
76	*4,051*	10,005	15,960	27,874	51,715	99,450	195,131
152	*9,094*	14,957	20,820	32,549	56,022	103,020	197,226
304	*19,602*	25,280	30,959	42,320	65,056	110,579	201,836
609	*42,299*	47,608	52,919	63,542	84,803	127,378	212,738
1,217	*94,415*	98,987	103,560	112,710	131,022	167,699	241,263
2,434	*225,539*	228,636	231,735	237,936	250,350	275,232	325,206

[a] The figures in the first row refer to firms specialized in the distribution stage ($Y_G = 0$), whilst the figures in the first column refer to firms specialized in the generation stage ($Y_D = 0$).

Figure 1. Estimated vertical economies for different combinations of generation and distribution