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THE ECONOMIES OF SCALE IN THE FRENCH POWER DISTRIBUTION UTILITIES

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Abstract[1]

This paper analyzes the cost structure of the French electricity distribution sector prior to the re-structuring reforms that have been initiated in 2005 and gradually implemented in the form of re-grouping certain activities across distribution units. The aim of this study is to assess the empirical evidence in support of these re-structuring measures. We explore the cost structure of the distribution units operating in France over the three year period. The data include 279 observations from 93 distribution units from 2003 to 2005, operating within the French electricity distribution network namely, *Electricité Réseau Distribution France* (ERDF). A Cobb-Douglas cost function is estimated using several specifications focusing on the analysis of the economies of scale and customer density. In order to account for the unobserved heterogeneity and its impacts on the economies of scale, we use a latent class specification. The results suggest that a majority of the distribution units can exploit statistically significant economies of scale. Further, the empirical analysis indicates that the unexploited economies of scale can vary considerably from one unit to another, not only because of variations in outputs but also because of the unobserved differences in networks and technological characteristics. In particular, the latent class approach can identify a group of distribution units that do not show any significant economies of scale. Further analysis suggests that such distributors are often located in metropolitan areas with high customer density.

[1] We thank Hélène Crespo for her general support and helpful comments.

1 Introduction

Along with the waves of liberalization and reform in European electricity industries, the French electricity sector has undergone several re-organization measures during the past few years. The French incumbent *Electricité de France* (EDF) was unbundled into separate entities representing network operations and competitive activities such as generation and supply. Since 2008, the EDF's independent subsidiary *Electricité Réseau Distribution France* (ERDF) has been in charge of power distribution in about 95% of the total distributed electricity in French territories.[2] Historically, the activities of ERDF namely, the management and maintenance of the medium and low-voltage lines form transformers to end-use consumers were organized in eight regional units. In the 1990's the power distribution sector has been gradually decentralized into about a hundred centers. While remaining under the direction of the regional networks, these distribution centers have benefited from a substantial degree of independence, especially in managing their everyday operation and maintenance. Starting from 2005, in order to increase the productive efficiency and exploiting the economies of scale, the company's management has gradually reversed the decentralization trend by re-grouping certain activities of some of the neighboring distribution centers. The reorganisation process was shaped around the expected efficiency gains from merging activities and the standardization of local units' operation and accounting practices. As a result, while retaining the overall size of distribution units, the managers have considerably increased the scale of certain operations such as customer service and technical maintenance. The extent of re-scaling varies across different functions, with particularly important changes in customer services that are currently managed at the regional level.

While the re-structuring measures were conceptually based on scale efficiency, there is however, little empirical evidence for the existence of the economies of scale in the context of electricity distribution in France. If the adopted re-grouping policies can be used as an indication, the evidence of economies of scale should be detected in the cost structure of the distribution units prior to these reforms. In fact, electricity reforms in the distribution sector have all but placed the issue of the economies of scale at the center of policy debates. Moreover, given that the adopted measures have taken a

[2] The remaining 5% is distributed by 160 relatively small municipal utilities.

differential approach toward various activities, one can argue that the optimal scale depends upon the type of the activity varying from a relatively small size for day-to-day network operation to a large scale for customer services. Before distinguishing the activities by their nature, one might question the relevance of re-grouping tendencies because of the lack of evidence for unexploited economies of scale, especially, as the current reforms are in contrast with previous decentralization measures.

In this paper we evaluate the importance of the economies of scale in the ongoing restructuring of the electricity distribution sector in France. Further, this study explores the cost structure of the distribution units in order to identify the extent and variation of the economies of scale across different units. The data includes 93 distribution units operating in France over the three year period between 2003 and 2005. This period basically covers the pre-regrouping period, in which the activities of the distribution units are entirely decentralized. In the analysis, we do not distinguish between different types of activity. However, we assume that distribution units might have various observed and unobserved characteristics pertaining to different levels of economies of scale. We can therefore identify specific units that can be considered with priority in the restructuring process.

From a methodological point of view, we should consider the fact that electricity distribution companies are characterized by considerable unobserved heterogeneity in their networks and environmental factors. In this paper, we use an econometric approach based on a latent-class specification that allows several categories of companies. While probably having fairly similar technologies, these categories could differ regarding their network and environmental characteristics, thus giving different scale economic properties. Using the latent-class model we can identify the economies of scale at each center, based on its characteristics that are not necessarily observed. The adopted model identifies four groups of distributors with distinctive levels of economies of scale.

The results can provide some insight to the policy and management aspects of the re-organization of the distribution networks. First, by quantifying a general level for scale economies, one can justify or reject the usefulness of the ongoing re-organizations. Secondly, by identifying which centers can have more potential for economic benefits of such re-organization, one can differentiate the priority of such reforms for various types of distributors.

The remainder of this paper is organized in the following way. Section 2 discusses the previous relevant literature. Section 3 presents the data and the model specification. Section 4 discusses the estimation results, while section 5 ends the paper with conclusions and suggestions for further research.

2 Review of the literature

The cost structure of the electric utility industry has been studied extensively over the past twenty years, following the development of duality theory which allows a technology to be analyzed using production, cost or profit functions. While many contributions confine the attention to estimation of cost functions for the generation of electric power, relatively few studies are available on the cost structure of transmission and distribution of electricity. The examples include Weiss (1975), Henderson (1985), Roberts (1986), Nelson and Primaux (1988) and Filippini (1996, 1998). Evidence of scale economies in distribution are for example Salvanes and Tjotta (1994) on Norway, Burns and Weyman-Jones (1996) on England and Wales, Farsi and Filippini (2009) and Filippini (1998) in Switzerland, Kwoka (2005) in the US and Yatchew (2000) on Canada, although these studies differ in methodology, choice of variables etc. They test different propositions and yield rather different interpretations of the measured cost effect of output change. The results provide some justification for some of the restructuring of distribution that has occurred, but they raise questions about the efficiency effects of mergers between electric utilities. Nevertheless, due to the fact that the distribution and supply unbundling was not effective at the date when all these studies were done, the data could include some supply costs and thus biased the results.

Burns and Weyman-Jones (1996) used mathematical programming (DEA) or stochastic frontier analysis (SFA) to evaluate the efficiency change. They draw up a comprehensive list of the factors these costs may depend upon: the maximum demand on the system, number of customers served (main determinants of distribution operating costs), the type of consumer, dispersion of the consumers, size of the distribution area, total kWh sold, system security, length of distribution line and the transformer capacity finding significant evidence of economies of scale.

Filippini (1998) estimates a flexible translog cost function for 39 Swiss municipal distribution utilities, where output was measured by the total number of kWh delivered and inputs consisted of labour, capital and purchased power. The results indicate the existence of economies of density for most output levels while economies of scale appear for small and medium-sized utilities only (the returns to scale is about 1.02 to 1.10). The policy suggestion of this study is thus a recommendation for mergers among the utilities.

Yatchew's (2000) specification comprise semiparametric variants of the translog cost function, where output (number of served customers) enters non-parametrically, while other variables (price of labor, price of capital, electricity delivered per customer, remaining lifetime of assets, load factor) are parametric. The estimation indicates that minimum efficient scale in Ontario is achieved by utilities with about 20,000 customers.

In 1998 Salvanes and Tjotta showed that from merging Norwegian small companies (less than 5000 clients), potential gains in terms of total cost[3] could be between 5.2% and 11.2%. For the case of larger companies (between 5000 and 10 000 clients) potential gains from merging could vary between 1.7% and 6.9%. Finally, merging the biggest Norwegian companies with more than 50 000 clients into one single company would result in gains of less than 1%. Thus, the authors suggest that several smaller distribution companies are a more efficient solution than a single big distributor, the optimal size being companies serving about 20.000 customers. They used a translog cost model, with the number of access contracts and an aggregate measure of energy output (GWh) as the outputs and price of capital, labor and purchased electricity as inputs.

Another study investigates whether mergers in the US distribution sector appeared as a consequence of the reforms, are likely to achieve cost efficiencies using a quadratic cost function (Kwoka, 2005). The central findings are that distribution is subject to economies of scale with respect to MWh of output, holding customer usage and customer density constant. But except at small scales of operation, the cost gradient is quite modest. In addition, there is no indication of cost effects from larger size of service territory. Moreover, the scale properties of the wires function are significantly stronger than those for the supply function. Not surprisingly, this is due to the capital intensity of the wires function, in contrast to the largely variable costs of supply. However, traditional models used in most of these studies regressions are discriminant

[3] These costs are evaluated by the authors and include capital and operational costs, but the definition and the construction of these costs are unclear.

and log-linear analysis containing parameters that describe only relationships between the observed variables. This study uses a latent class model which differs from these by including discrete unobserved variables. As latent class models do not rely on the traditional modeling assumptions which are often violated in practice (linear relationship, normal distribution, homogeneity), they are less subject to biases associated with data not conforming to model assumptions.

Hogan (1993) discusses the efficient organization of production in the electric industry. As he points out any meaningful discussion of deregulation and re-organization should be based upon a clear understanding of the cost structure of the electric power industry. Most of the studies on the electricity distribution industry have utilized long-run cost functions which invoke the assumption that electricity distribution utilities are in static equilibrium, using all inputs at their optimal levels. This study presents a specification that allows for the possibility that firms are not in static equilibrium with respect to one factor of production, the stock of capital. If it is the case that the utilities are not in equilibrium with respect to this quasi-fixed input, then measures of economies of scale based on estimates of the long-run cost function may be biased.

There are two plausible arguments supporting the claim that electricity distribution utilities have maintained a greater capacity than the optimal levels implied by minimizing total costs. First, the capital embodied in the distribution lines and transformers is long-lived, causing adjustment to a change of the time profile of electricity demand costly. Furthermore, distribution capacity is planned and built on the basis of long-term load forecasts. Second, municipalities give an exclusive concession to a distribution utility in exchange for guaranteed service to all resident consumers. Therefore, the distribution utilities are legally obliged to maintain excess capacity so as to meet sudden increases in the demand and to guarantee service. This again argues for a quasi-fixed capital stock in electricity distribution.

The restricted variable cost function model is used to model the production structure of the electricity distribution utilities. This variable cost function takes account of divergence from the optimum in that the quantity of physical capital cannot be adjusted to achieve minimum total cost during the period of observation for a given set of input prices and the quantity of outputs.

This study uses a variable cost function as a function of outputs and the quasi-fixed input that is the distributor's capital stock. As we will see later we assume that the input prices are similar across the distributors.

3 Model Specification and data

The distribution units operating within French electricity distribution network ERDF, are in charge of delivering electricity to end-use consumers, maintenance and customer service activities including metering. The distribution units are administered by eight regional centers. Each center is organized in several sections. The variables include itemized costs, asset values, number of customers and technical variables such as length and capacity. The input electricity is provided by the French national transmission network that is, *Réseau de Transport d'Electricité* (RTE). It is assumed in this study that the distribution units minimize their annual operating costs given the output determined by electricity demand, the capital stock determined through a long-term and mainly central decision-making process at the regional level, and the input prices such as prices of labor and material. For the present analysis, due to lack of accurate data for prices, we assume that the input factor prices are uniform across all the distribution units. This is a realistic assumption for the distribution centers included in this analysis, because they all belong to a single mother company, thus follow similar rules for employment and also use the same electricity network for their input electricity. Moreover, this simplifying assumption does not seem to considerably affect the results, because the variations in input prices across units are most probably random and uncorrelated with the explanatory variables in the model. In fact, operating in a single administration, the units probably use similar suppliers for the required materials and equipment. And with similar salary systems, the variations in labor prices are expected to be mainly due to completely random factors such as the age of the employees mix.

The general form of the cost function specification can therefore be written as:

$$C = C(CU, AS, K, D_t) \qquad (1)$$

C: Total OPEX (Euro) for networks and customer-service activities

CU: Total number of the low-voltage customers

AS: Service area size (km^2)

K: A measure of the distributor's capital stock

D_t: A vector of year indicators (2003 is considered as the omitted category).

This is a variable cost function, in which the capital input is considered as a quasi-fixed input that does not enter in the choice variables of the optimization process. The dependent variable includes the costs of operation and maintenance of the distribution network, metering and other customer services. These costs include the expenses related to the repair and maintenance of the entire distribution network. These maintenance costs occasionally include relatively small investment-like costs specified as 'preventive maintenance'. The capital expenditures and investment costs, taxes and royalties and also the costs of activities related to client management and contracts are excluded. The latter activities are generally concentrated at the regional level. Costs and all other monetary variables are converted to 2005 prices using the Consumer Price Index.[4] The main output is measured by the number of customers. The middle-voltage customers that constitute a little fraction of the number of customers are not included in this variable. We contend that this variable is an adequate measure of the main activities of the distributor company, which in contrast with the delivered electricity, also represents the activities related to metering and end-use connections etc. In any case, this variable is strongly correlated with the distributed electricity (correlation coefficient of about .94), suggesting that very similar variations are captured by the two variables.

The second important output characteristic that measures the activities of a distribution utility is the network extension or size. This factor represents an aggregate measure of the distance over which the distributed electricity flows before reaching the end-use consumer. We considered the area size to represent this factor. We also tried an alternative specification in which the area size was replaced by network length. As we see later, the estimated remaining coefficients do not show considerable differences. Ultimately, we preferred the area size in the final model because the network length capture a main part of the distributor's capital stock. Two alternatives are considered for capital stock: A monetary value defined as the distributor's total assets in net accounting value ('000 Euro) and a physical measure defined by the installed capacity of transformers (MVA). While the former is expected to be more representative of the total

[4] We used CPI for all households excluding tobacco prices (Source: INSEE economic indicators at www.insee.fr).

capital stock, the latter has the advantage of smaller potential measurement errors. However, the alternative models do not show any significant difference regarding the main coefficients. Considering this close similarity, we focus on the model with monetary measure of capital, which has the advantage of a better overall representation of the capital stock.

In the choice of the model specification given in Equation (1), we have considered other alternatives. For instance, we tried other model specifications including additional variables such as delivered electricity, customer density and two separate variables for network lengths for low and medium voltage electricity. We also tried several models replacing the included variables with other variables, such as replacing number of customers with the delivered electricity. Generally the results (available upon request) indicate that the effect of additional variables is in most cases either statistically insignificant, otherwise their inclusion makes some of the other coefficients insignificant. This suggests that with the small size of the sample, a relatively parsimonious model can be more helpful in identifying the main effects of interest.

The econometric analysis is based on 279 observations from 93 distribution units operating within ERDF, over a three-year period from 2003 to 2005. A descriptive summary of the variables included in the models is provided in Table 1.

Table 1: Descriptive statistics (279 observations from 93 distributors)

Variable		Mean	Std Dev	Minimum	Maximum
C	Variable costs OpEx (€ million)	23.49	12.03	10.58	115.55
CU	# of low-voltage customers	338'437	186'637	109'435	1'596'126
NT	Network Length (km)	13'320	6'143	4'060	32'743
K	Assets book value (€ million)	342.71	143.55	128.92	937.12
AS	Service Area Size (km^2)	5'473.46	3'158.07	107	1'3871
CA	Total Transformer Capacity (MVA)	1442	613	412	4526
Q	Distributed Electricity (GWh)	3'673	1'845	1'001	14'364
CD	Customer density (customer per km^2)	445	1'663	17	14'917

All monetary values are in terms of 2005 Euros based on French CPI.

The regression coefficients are then used to estimate the economies of scale and customer density according to the following expressions:

$$ES = \left(1 - \frac{\partial \ln C}{\partial \ln K}\right) \cdot \left(\frac{\partial \ln C}{\partial \ln CU} + \frac{\partial \ln C}{\partial \ln AS}\right)^{-1}$$
$$ED = \left(1 - \frac{\partial \ln C}{\partial \ln K}\right) \cdot \left(\frac{\partial \ln C}{\partial \ln CU}\right)^{-1} \qquad (2),$$

where *ES* and *ED* are respectively the rates of the economies of scale and the economies of customer density from a variable cost function.

Scale economies exist if increasing production lowers average cost. Following Caves et al. (1981) we define economies of scale as the proportional increase in total cost resulting from a proportional increase in output and area size, all other factors being constant. We will have economies of scale if *ES* is greater than 1, and accordingly, we can identify diseconomies of scale if *ES* is below 1. In the case of *ES* equal to 1 no economies or diseconomies of scale exist, that is, optimal scale. Equations (2) provide the long-run economies of scale and economies of density as defined by Nelson (1985). The long-run economies of scale account for the possible increases in capital stock thus, include an adjusting term representing the resulting changes in costs.[5]

The existence of economies of customer density implies that the average costs of an operator decrease as number of customer increases. Economies of density exist if the above expression (*ED*) has a value greater than one. For values of *ED* below one, we identify diseconomies of density. In the case of *ED* = 1, the company's number of customers minimizes its average costs given the area (network) size.

Slightly different is the definition of economies of scale (*ES*). Here, the increase in variable costs is brought about by an increase in company's scale that is in both number of customers and the area size. However, since the changes in number of customers and network size are inter-related, the definition of scale economies requires an assumption in this respect. The commonly used definition used in Equations (2), is the one proposed by Caves et al. (1984), which assumes that any increase in scale raises all the output variables with the same proportion.

[5] Following Caves et al. (1981), it is also possible to compute the short-run economies, referred to as the economies of capacity utilization. In this case, the capital stock is assumed to remain constant when the output or number of customers rises. Here we focus on the long-run economies. This distinction is especially important in the context of scale economies (*ES*), because it is unlikely that an extension of area size occurs without an increase in the capital stock. The estimated values here also account for the economies (or diseconomies) of scale that can be achieved by extending the capital stock.

The value of the economies of scale is a function of capital stock and outputs. The procedure for measuring economies of scale with Equations (2) in the presence of quasi-fixed input have been continually discussed in the literature: Caves et al. (1981) have proposed evaluating *ES* at the actual capital stock, while Friedlander and Spady (1981) and Oum et al. (1991) suggested the evaluation at the equilibrium stock of capital. Braeutigam and Daughhety (1983), Nelson (1985) and Oum et al. (1991) demonstrated that the value of economies of scale may differ between the two alternative measurement methods.

The long-run equilibrium stock of capital, K^* can be computed by minimizing the short-run total cost (*SRTC*) function:

$$STRC = C + P_k.K \qquad (3),$$

where P_k is the user cost of capital, and C is the variable costs. If K^* denotes the optimal value of capital stock which minimizes *SRTC*, then at $K = K^*$, we have:

$$\frac{\partial SRTC}{\partial K}\bigg|_{K=K^*} = \frac{\partial C}{\partial K}\bigg|_{K=K^*} + P_c = 0 \qquad (4).$$

This implies that utilities substitute capital for variable inputs such as labor until the marginal reduction in variable cost equals the user cost of capital. Therefore, once the coefficients of the variable cost function are estimated and once the user cost of capital is defined, it is possible to calculate K^* by numerically solving the envelope condition expressed in Equation (4). Therefore, the estimation of the economies of scale at optimal capital stock requires the knowledge of the user cost of capital or capital price. However, as Norsworthy and Lang (1992) point out, the definition of the price of capital services is a contentious issue that requires some strong assumptions. Moreover, given that the utilities are likely to have excess capacity in order to respond to their obligations in meeting long-term load forecasts, the assumption of optimality of capital stock might be unrealistic. Therefore, in this study, following Filippini (1996), we estimate the economies of scale and density at the actual levels of capital stock.[6]

[6] A corollary of the optimality condition (4) is that the coefficient of the capital stock should have a negative sign in a variable cost function that takes capital as a fixed input. However in many studies on the cost structure of electric power utilities (e.g. Nelson, 1989; Hammond, 1992), the first-order coefficient for capacity was found to be positive. As illustrated by Cowing and Holtmann (1983), a cost elasticity of capacity greater than zero, indicates that a utility is employing an excess amount of the quasi-fixed factor. An alternative interpretation provided by Filippini (1996) relates the unexpectedly positive effect of capital stock to multi-collinearity problems and measurement errors in specifying capital stock.

4 Econometric approach and results

For the empirical analysis, given the heterogeneous types of companies, we use a latent class model.[7] In this model unobserved differences between firms' technological types is considered by separate classes of companies as in Orea and Kumbhakar (2004). As noted above, the various technological properties such as returns to scale are not necessarily due to different technologies. Companies using a similar technology might show different levels of economies of scale if they operate in different networks and various environments. The intuition behind the latent class model can be simplified as a two-stage analysis.[8] In the first stage the companies are classified into several distinctive groups regarding their cost structure. In the second stage a separate cost function is estimated for each one of the categories.

The latent-class model is a natural choice consistent with the view that the networks included in the sample entail more than one typical set of technological properties. The main problem of such models is that they require a larger number of parameters to estimate. Considering the limited number of observations in our case, this difficulty implies a limiting constraint on the number of explanatory variables included in the model, we decided to use a Cobb-Douglas functional form.

Using the specification of Equation (1), the Latent-Class Cobb-Douglas (LCCD) model can be written as:

$$\begin{aligned}\ln C_{it} &= \alpha_i^{(CU)} \ln CU_{it} + \alpha_i^{(AS)} \ln AS_{it} + \alpha_i^{(K)} \ln K_{it} \\ &\quad + \sum_{t=2004}^{2005} \delta_i^{(t)} D_t + \alpha_i^{(0)} + \varepsilon_{it}\end{aligned} \qquad (5),$$

where subscripts i and t denote the company and $\varepsilon_{it} \sim \mathrm{N}(0,\sigma_i^2)$. The model parameters $\alpha_i^{(CU)}, \alpha_i^{(AS)}, \alpha_i^{(K)}, \delta_i^{(t)}, \alpha_i^{(0)}$ and σ_i discrete random parameters identified in J classes distributed across firms, giving each firm a single firm-specific realization. The distribution of these random parameters is given by the following rule:

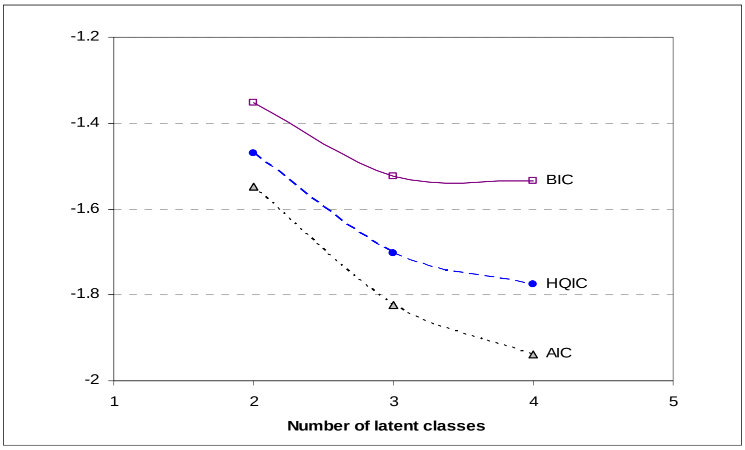
[7] Greene (2007) and Cameron and Trivedi (2005) provide a general discussion of latent class models. For the model's application in production economics see Greene (2008, 2005).

[8] It should be noted that, the latent-class model is estimated in a single step. The two-stage procedure is only a useful way to describe the model.

$$\{\alpha_i^{(CU)}, \alpha_i^{(AS)}, \alpha_i^{(K)}, \delta_i^{(t)}, \alpha_i^{(0)}, \sigma_i\} =$$
$$\{\alpha_j^{(CU)}, \alpha_j^{(AS)}, \alpha_j^{(K)}, \delta_j^{(t)}, \alpha_j^{(0)}, \sigma_j\} \text{ with probability } P_j \qquad (6),$$
$$\text{with: } j=1,2,...,J \text{ and: } \sum_{j=1}^{J} P_j = 1$$

where $\alpha_j^{(CU)}, \alpha_j^{(AS)}, \alpha_j^{(K)}, \delta_j^{(t)}, \alpha_j^{(0)}, \sigma_j$ $(j=1,2,...,J)$ are the model parameters to be estimated, and J is the number of latent classes that is set prior to the regression. The choice of J is usually based on diagnostic criteria such as Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), or that proposed by Hannan and Quinn (HQIC). Our preliminary analysis indicates that the model has serious numerical problems with J>4, that make the convergence practically impossible. Figure 1 depicts the variation of these criteria as a function of the number of latent classes. As this figure illustrates, all three information criteria also indicate that by increasing J from 2 to 3, the improvement is considerable but the gain will substantially decrease from J=3 to 4, suggesting that the optimal number of classes is reached.

Figure 1: Specification of the number of latent classes



We have also tried a simple specification that could converge with 5 or more latent classes. The results of that analysis (available upon request) suggest that with more than 4 classes, the additional classes become degenerate, that is, they include only one company. The results also show that some of the diagnostic criteria deteriorate with J>4. In particular the BIC shows a clear optimal value at J=4. Considering these results we focus on four latent classes. The estimation results are given in Table 2.

Table 2: Estimation results (LCCD)

	Class 1	Class 2	Class 3	Class 4
Number of customers (*CU*)	1.285	0.644 **	0.674 **	0.470 **
	(0.797)	(0.039)	(0.038)	(0.066)
Service area size (*AS*)	0.063	0.080 **	0.084 **	0.057 **
	(0.089)	(0.008)	(0.015)	(0.026)
Assets book value (*K*)	-0.400	0.183 **	0.088 *	0.331 **
	(0.820)	(0.039)	(0.047)	(0.099)
Year 2004	0.048	-0.067 **	-0.027	-0.125 **
	(0.344)	(0.028)	(0.029)	(0.040)
Year 2005	0.472 **	-0.191 **	-0.115 **	-0.253 **
	(0.179)	(0.015)	(0.016)	(0.073)
Constant	5.086 **	5.775 **	6.635 **	6.532 **
	(1.516)	(0.201)	(0.209)	(0.441)
Std. dev. of the stochastic term (σ_j)	0.119 **	0.060 **	0.049 **	0.048 **
	(0.034)	(0.004)	(0.004)	(0.008)
Prior class probability (P_j)	0.086 **	0.452 **	0.348 **	0.114 **
	(0.029)	(0.058)	(0.060)	(0.038)

Standard errors are given in parentheses. * p<.1; ** p<.05

These results point to distinctive technology classes among the distribution centers. Interestingly in class 1, accounting for about 9% of the centers, the coefficients related to output and capital stock do not show a statistically significant effect. Class 1 is therefore a peculiar category for which the estimation results cannot provide any useful estimate of economies of scale. With the exception of class 1, all the estimates coefficients are plausible: both customer numbers and area size have a positive effect on variable costs. These coefficients are also comparable across different classes. The results suggest that the temporal effects are important. In particular there is substantial change in 2005 compared to other two years in the sample. However, the relatively large magnitude of the estimated temporal changes in costs suggest that these estimates should be considered as statistical adjustments of the intercepts rather than a systematic trend of technical progress.

The results of Table 2 indicate a positive effect of capital stock, suggesting excess capacity. The positive impact of capital on variable costs might appear counter-intuitive as the theoretical substitution of labor and capital suggest that additional capital should decrease the variable costs. However, in an environment with excess capacity in which the provision of capital is for responding to long-term increases in demand, higher capital stock will potentially require additional labor services for maintenance.

There is however, another issue that might contribute to the apparent effect of capital: the measure of capital stock is usually correlated with outputs, therefore it might capture some of the effects that should be associated with the variations in output. In this case, occasionally referred to as 'multi-collinearity', the economies of scale obtained from Equations (2) could be biased. In order to avoid such effects, we also calculated similar models without capital stock. This alternative specification is obviously an improper model for estimating a variable cost function, but is used only to check if the positive effect of capital is due to correlations with output characteristics. The results (available upon request) regarding the coefficients of outputs are not substantially different from those reported here, suggesting that the positive effect of capital stock is not an artifact of mechanical correlations in the data.

The estimated economies of scale and density from the latent class model, based on Equations (5), are listed in Table 3. It should be noted that given the Cobb-Douglas functional form, these values do not vary with outputs within each class. Namely, each latent class is assumed to have single values of *ES* and *ED*. As expected, class 1 does not show any statistically significant economies. The other three classes show however significant economies of scale and density.

Table 3: Economies of scale and customer density (LCCD)

	Class 1	Class 2	Class 3	Class 4
Economies of Scale (*ES*)	1.039	1.129 **	1.203 **	1.270 **
	(.109)	(.029)	(.031)	(.071)
Economies of Density (*ED*)	1.089	1.269 **	1.353 **	1.424 **
	(.087)	(.028)	(.028)	(.083)

Significantly different from 1 at: * p<.1; ** p<.05

Standard errors (given in parentheses) are computed using the delta method.

The results of the latent class model can be used to specify the companies that have more or less potentials for such economies. In order to illustrate how this classification can be used we turn first to identify these latent classes concretely and if possible to describe them with some observed characteristics. Our identification strategy was based on integrating some observed characteristics of the companies into the latent class model such that the probabilities P_j of Equation (6) can be predicted by those variables. This was not successful, as all the attempts with several variables such as customer density, network length and delivered electricity volume indicated that adding these variables to the latent class model (as explanatory variable for probabilities P_j) results invariably in non-convergence or statistically insignificant results. Therefore, we try to describe the classes with a post-estimation approach. This approach consists of calculating for each given company included in the sample, its posterior probability of belonging to each one of the four classes. These posterior probabilities are calculated based on the estimated values of the coefficients of each class and the average residual term for the specific company (for more details see Greene, 2007). The results are summarized in the last row of Table 4.

The estimated posterior probabilities show an interesting pattern. Not only most of these values are quite close to 1, suggesting that specific companies can be distinguished without much suspicion, the results indicate 100% probability for the eight companies that are identified as class 1. In general the minimum class probability is always greater than 50%, which is a reasonable value for a model with four classes. The small values of standard deviation of the posterior probabilities (Table 4) also suggest that the model provides a reasonable explanatory power in distinguishing the technology classes.

Table 4: Identifying the classes

	Class 1	Class 2	Class 3	Class 4
CU ('000)	598 (421)	317 (110)	312 (135)	306 (187)
AS (km^2)	2844 (3005)	5759 (2763)	5060 (2611)	7741 (4877)
CD (per km^2)	2399 (5086)	186 (575)	333 (853)	338 (701)
CA (MVA)	2021 (1067)	1419 (401)	1379 (600)	1277 (725)
K (€ million)	453 (221)	333 (116)	323 (131)	358 (151)
NT (km)	10823 (6276)	13065 (5520)	12963 (6072)	17566 (7849)
Q (GWh)	5778 (3710)	3589 (1220)	3449 (1550)	3077 (2060)
Posterior P_j	1.000 (.000)	0.964 (.087)	0.926 (.100)	0.973 (.073)

Standard deviations are given in parentheses.

Table 4 also provides a descriptive summary of a selected number of observed variables for each class of companies as identified by the estimated posterior probabilities. These results indicate a considerable variation in observed characteristics within each class. However, we can distinguish in an approximate manner, certain features that are common for each class. Obviously such a classification bears on our subjective judgment and is not uniquely determined result of the estimations. A possible explanation of these classes could be formulated as follows:

Class 1: High customer density (CD)

Class 2: Medium network (medium CD)

Class 3: Medium network (low CD)

Class 4: Large networks (medium CD)

These results suggest that even the relatively large networks included in the data, can benefit from the economies of scale. The only group that appears to show no statistically significant benefit from extension is the networks with high customer density. Posterior probabilities indicate that this group includes eight companies that are located in the bigger metropolitan areas. The results of the latent class model suggest that these distribution centers could be singled out for organizational reforms. This implies that these centers do not need to be considered in a general policy program for re-organization and would probably require more tailored management policies as, determining certain level of scale economies is not possible in this group. This suggests that the policy conclusions should be based on more detailed case analyses.

5 Summary and Discussion

We have analyzed the cost structure of French electricity distributors operating between 2003 and 2005. The purpose of the analysis was to estimate the long-run economies of scale and density. The research question is whether the structure of the distribution networks can be improved regarding the scale of production, for instance by merging relatively small neighboring networks and combining their activities, or conversely by dividing them to smaller units. The trends in the re-organization of French distributors since 2005 were in favor of grouping certain activities across several distribution units, suggesting that the size of the distribution companies is smaller than the optimal size. We examined the question of scale economies with the data prior to these reforms and quantified the extent of potential economies that could be gained by increasing the scale. Moreover, we identified in which type of companies these economies could be expected to be relatively high.

The empirical results indicate the presence of four different categories of distribution units among those included in the sample. The results suggest that the economies of scale and density are statistically insignificant in one of these four categories. This group of distribution units basically consists of networks located in metropolitan areas with high customer density. The relatively high standard errors in this class also suggest that this group could have certain peculiar characteristics varying considerably from one center to another. Therefore, determining certain level of scale economies is not possible in this group, which suggests that the policy conclusions should be based on more detailed case analyses.

Excepting this peculiar category, all other classes (amounting to about 90 percent of the sample) show a statistically significant level of economies of scale. The results point to several systematic differences across these three classes. The main differences can be identified in the effect of capital stock and year indicators. They also can be used to distinguish three groups regarding the economies of scale. In particular two of these classes (class 3 and 4) consisting of about half of the distributors included in the sample, show relatively high levels of economies of scale and density. Overall, the results confirm those highlighted in the first analysis in that a big majority of the distribution centers could exploit significant economies of scale.

This paper's results are thus supporting the reorganization process led by ERDF after 2006. This process consisted in regrouping certain activities at a regional level, the local units being in charge only of the the human resources, day-to-day operating decisions (management of electricity network performances) and customer service (Grasland, 2006). All the long-term strategic decisions are taken at the regional or national levels and some tasks have been externalised (maintenance and repairs of connections with the high-voltage transmission system, constructing and maintaining connections to the transmission network). This was, certainly, a reorganisation process shaped around the specific activities of the distribution "process", but the implicit objective was to reach efficiency gains from merging these activities. After 2008, new supra-local units were created in order to merge business-specific activities. Thus, 23 network operation units are now in charge of electricity network-related activities and 18 units are in charge of gas activities, 24 units are in charge of all customer and retailer related issues, and 8 units are regrouping logistics at regional level.

This reorganisation consisting in regrouping activities for reaching critical size for a given task (electricity engineering, customer services, supply activities etc.) shows the distributor's efforts to exploit the economies of scale. The analysis presented in this paper provides some empirical evidence for the existence of such economies. However, it should be noted that these results are based on the available data over a limited period of time. Therefore, the numerical results presented in this report and their interpretation should be considered with caution.

6 References

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