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by

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The evolution and main determinants of productivity in Brazilian electricity distribution 1998-2005: an empirical analysis

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Abstract:

This paper estimates changes in the productivity of the Brazilian electricity distribution sector using Data Envelopment Analysis (DEA) on a panel of 18 firms from 1998-2005. The study decomposes the productivity change of these distribution firms in terms of technical efficiency; scale-efficiency and technical progress. This exercise aims to help the understanding of the main determinants of the evolution of productivity, focusing its relationship with the restructuring process implemented in the 1990s. TFP index records a yearly positive growth rate of 1.3% in the whole period under analysis for all firms. Technical change was the main component behind this evolution, with an average growth of 2.1% per year, while technical efficiency presented a yearly negative performance of -0.8%. The results prove that, in general terms; the incentives generated in the reform process do not seem to have led the firms to behave in a more efficient manner.

Keywords: electricity distribution, productivity decomposition, Brazil. L94

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1. INTRODUCTION

The main aims of the Electricity Sector Reforms are to introduce competition into electricity generation and supply, and to improve the efficiency of the natural monopoly activities of distribution and transmission through structural and regulatory reforms. The regulatory reforms have tended to move away from traditional rate of return regulation towards incentive-based regulation models. Nevertheless, soon after liberalization, it was made evident that structural reforms in some countries were insufficient to guarantee a competitive market performance. Several problems arose because of the excessive market concentration and the existence of incentives to capacity investments in a long term perspective, among others.

The target of the regulatory reforms is to provide the utilities with incentives to improve their investments and operating efficiency and to ensure that consumers benefit from the efficiency gains. Incentive regulation can take different forms, but the most common form involves the application of some form of price cap regulation. Price cap regulation specifies the maximum rate at which regulated prices may change. In practice, these prices are usually set to increase at a rate equal to the rate of increase in the consumer price index (CPI) minus a so-called productivity offset, designated as X, and thus, it is called CPI-X regulation[1].

In developing countries the burden of subsidies, low service quality, non collection rates, high network losses and poor service coverage have meant that many governments are no longer willing or able to support the existing arrangements (Newbery, 2002)[2]. Until the 1980s, the regulatory framework of the Brazilian Electricity Industry (BEI) was mainly characterized by the practice

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[1] Estimating X is a complex issue. In some cases, the regulator may choose to set different X-factors for different firms in an industry if some firms are more inefficient in relation to other firms. In practice, during the preparation for the tariff revision, regulators will generally study the previous total factor productivity (TFP) growth in the industry and the present levels of firm-level efficiency to help them set the X factor for each firm in the industry. If the firm can obtain cost increases below the allowed CPI-X price increase, they can pocket the difference. This is the incentive aspect of the method.

[2] In Latin America the debt crisis of the 1980s interrupted capital flows into the region and it became difficult for the public sector to maintain the required financing for infrastructure investment. Some Latin American countries clearly sacrified competitive market structure to the need to raise extra privatization revenue (e.g. in Chile)

of cross subsidies, the central planning of expansion, the cost of service practice, and the presence of state-owned firms in all segments, generation, transmission and distribution. The financial deterioration of the state-owned firms during the 1980s boosted a restructuring process. In the 1990s the pro-market reforms were implemented, with the objective of promoting a growth of the sector's investment rate, by attracting the private capital and improving the sector's productivity. In the distribution segment, the restructuring process took place by the privatization of most of the firms, with the exception of some smaller state-owned companies. At the same time, different acts have changed the tariff policy using a price cap system.

This paper is devoted to assess the evolution of the efficiency and productivity of the Brazilian electricity distribution sector from 1998-2005. This exercise aims to help in the understanding of the restructuring process implemented in the 1990s. Jamasb and Pollitt (2007) point out the importance of efficiency and productivity studies to illustrate the performance of electricity industry before and after regulatory reforms in different countries[3]. The results of this paper mean to complete the analysis of other studies carried out in the Brazilian industry reaching up to 2005, just after the conclusion of the privatization process. One objective of this work is to test the poor performance of some firms in Brazilian electricity distribution showed in previous works.

Regulatory and structural reforms in electricity industry would normally be expected to: increase investment, increase number of customer connected, reduces losses and cut number of employees between others. To be able to incorporate the various sources of productivity changes it is used a measure that account jointly for the multiple outputs and inputs used in the production of these outputs. This is what TFP (Total Factor Productivity) try to do. DEA Malmquist approach is employed to estimate the TFP on a panel of 18 firms. This methodology requires only the physical data quantities of input employed and output produced if only technical and scale efficiency is estimated. For this reason, in this paper, we use this methodology to decompose the productivity

[3] While these studies calculate the firm-efficiency effects of reforms, the overall economic efficiency resulting from reforms can best examined by social cost-benefit analysis.

evolution of the distribution firms in terms of technical efficiency, scale-efficiency and technical progress[4].

The paper is organized as follows: the second section shows the DEA technique in a multi-output multi-input context. The third section provides a brief presentation of the regulatory framework of the Brazilian electricity distribution sector, covering both the restructuring process of the 1990s and the current situation and also briefly surveys the existing literature on the topic in Brazil. The fourth section describes the data and the variables and presents the empirical results. Finally, the fifth and last section displays, in a nutshell, the main findings of this study.

2 – METHODOLOGY

Productivity is generally defined in economics as the ratio of what is produced to what is required to produce. Productivity measurements have a long history. The earliest approach to productivity measurement was based on a single or a partial factor productivity measurement. Although easy to calculate, this index is too simple in practice and could provide a misleading picture of performance when there is more than a single output or a single input. In fact, firms usually use multiple inputs to get multiple outputs and so productivity measurement must take this into account using the TFP measurement. Thus, the TFP is a generalization of the single-factor productivity measures[5].

TFP growth refers to the change in productivity over time. There are several approaches to the productivity measurement. In order to take into account the contribution of efficiency change to productivity change, we are going to use a frontier approach. In the frontier approach a best practice frontier, which each firm is to be compared, has to be estimated. It could be done using non-

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[4] Abbott (2006) indicates that utilities such as electricity supply often operates in markets, which lack prices and cost determined under competitive conditions. In cases such as these, the usual market indicators of performance, such profitability and rates of return, cannot be used to gauge an industry's economic performance. In these circumstances, indicators of the level of change of productivity and efficiency are more appropriate indicator of an industry's performance.

[5] The partial factor approach has a disadvantage in that it can be misleading when looking at the change in productivity of an industry. If the process has simply involved a substitution of capital for labour, then a TFP indicator that indicates a more modest increase in overall productivity would be a more appropriate measurement of productivity.

parametric[6] or parametric[7] techniques but, in both cases, some assumption about technology must be done. Both approaches have merits and drawbacks.

The two most often used methods are: Data Envelopment Analysis (DEA) in the non-parametric group and Stochastic Frontier Analysis (SFA) in the parametric one[8]. Although several studies compare DEA and SFA, the literature is not clear on which approach is superior. DEA has the advantage of requiring minimal assumptions regarding the structure of production, while SFA requires the specification of a particular functional form for the technology and also requires the assumption of a distributional form for the inefficiency term. DEA can easily deal with multiple outputs and inputs and SFA too, but only using distance functions[9]. On the other hand, SFA has the advantage that it allows standard statistical tests to examine the significance of variables included in the model and it attempts to account for the effects of noise data, while DEA assumes no noise in the data[10].

There is no consensus on the specific model or technique used, but frontier techniques are the most widely used in electricity distribution. Mainly, the choice of the method depends partly on the data available. DEA can be implemented in a smaller data set, however, it is recommended to keep the number of variables under control in order not to get an unreasonable number of companies on the frontier. Finally, DEA is flexible enough to allow the use of physical and monetary values just as input or output variables, what can be very useful in the context of electricity distribution.

Measuring and decomposing TFP using the Malmquist TFP index

The Malmquist TFP index is chosen to analyze the productivity change and its decomposition using DEA. Malmquist productivity indexes were introduced by

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[6] Like Data Envelopment Analysis (DEA) and Free Disposable Hull (FDH).

[7] It could be linear programming or econometric techniques. The econometric group is also divided into two: deterministic and stochastic frontiers.

[8] A detailed analysis about the relative merits of all of these techniques is out of the scope of this article, but a good summary could be found in Färe et al (1997).

[9] SFA could also do it considering a cost function at the expense of making behavioural assumption.

[10] Recent developments surveyed by Simar and Wilson (2000a, 2000b y 2005) allow making statistical inference and hypothesis testing with DEA and other nonparametric efficiency estimators.

Caves et al. (1982). They named these indexes after Malmquist, who proposed to construct input quantity indexes as ratios of distance functions (Malmquist, 1953)).

The distance function, introduced by Shephard (1953, 1970), allows estimation of the relative efficiency of firms in relation to the technological frontier described by the distance function. Distance functions describe a multi-input, multi-output production technology without making behavioural assumption (such as cost minimization or profit maximization) which is especially suitably in regulated industries. Another important distance function's advantage is that input and output prices are not needed.

The distance function can take an input orientation or an output orientation. An input distance function characterizes the production technology by looking at a minimal proportional contraction of the input vector, given an output vector. Conversely, an output distance function considers a maximal proportional expansion of the output vector, given an input vector. In this paper, we follow an input-oriented approach (see Jamasb and Pollitt, 2001) as demand for electric distribution services is a derived demand that is beyond the control of utilities and has to be met.

Malmquist Index through DEA Technique

DEA provides a non-parametric technique to measure the relative efficiency of each firm. It utilizes a piecewise linear programming to calculate the efficient or best-practice frontier of a sample (see Farrell, 1957; Färe et al., 1985).

Fare, et al. (1997) showed that the majority of the empirical studies that measure the Malmquist productivity index have used DEA. In a DEA context, estimates of the Malmquist productivity index, as well as its sources of growth, are obtained by computing appropriate ratios of distance function values corresponding to the constant return to scale (CRS) and the variable returns to scale (VRS) technologies.

The input-oriented Malmquist compares the input requirements for producing output level y_t with period t technology, with the input that would have been required if the production technology was the same as that in a later period, s. Thus, x_t is essentially being compared with what would have been required under technology s. Following Färe et al. (1994) the Malmquist Productivity index for i[th] firm is given by:

$$TFPs/TFPt = \frac{d_V^t(y_t,x_t)}{d_V^s(y_s,x_s)} * \left[\frac{d_V^s(y_s,x_s)}{d_V^t(y_t,x_t)} * \frac{d_C^t(y_t,x_t)}{d_C^s(y_s,x_s)}\right] * \left[\frac{d_C^s(y_t,x_t)}{d_C^t(y_t,x_t)} * \frac{d_C^s(y_s,x_s)}{d_C^t(y_s,x_s)}\right]^{0.5} \quad (1)$$

Where, y and x are inputs and outputs vectors in each period of time, s and t are period of time such as s>t and, finally, C and V denote CRS and VRS frontiers, respectively.

The equation (1) defines the total factor productivity change (tfpch). From this equation, it is possible to get the following indexes:

- Technical efficiency change (effch), a ratio of two distance functions which measures the change in the technical efficiency between the period of change.
- Technological change (techch), a measure of the technological change in the production technology, an indicator of the distance covered by the efficient frontier from one period to another.

Considering the hypothesis of VRS technology, the technical efficiency change (effch) index may be further decomposed into two components, the pure technical efficiency change (pech) and the scale efficiency change (sech)[11].

[11] This decomposition has been criticized by some authors because it measures technological change using the constants returns to scale technology instead of the variable return to scale technology. Various alternatives have been proposed, but none of them have gained widespread acceptance. See Grifell and Lovell (1999) and Balk (1999) for discussion in this issue.

- Pure technical efficiency change (pech), a component of the technical efficiency change which is obtained by re-computing efficiency change under the variable return to scale,
- Scale efficiency change (sech), the ratio of efficiency under CRS and the same efficiency under VRS. Both sech and pech are components of effch.

Equation (1) shows six distance functions must be calculated: four defined under CRS and two under VRS. A standard way of presenting the underlying optimization program used here is:

$$\min_{\theta\lambda} \theta, st \qquad \begin{aligned} &-\mathrm{yi} + \mathrm{Y}\lambda \geq 0 \\ &\theta \mathrm{xi} - \mathrm{X}\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned}$$

where λ is a vector describing the percentage of the other operators used to construct the efficient operator, *X* and *Y* are the inputs and output vectors of the efficient operator, and X_0 and Y_0 are the inputs and outputs of the operator under evaluation. The value of θ reflects the efficiency of this operator.

Finally, there are several ways to evaluate the influence of environmental variables in a DEA framework (Rouse, 1996). In this paper we follow the simplest method of dealing with them: incorporate environmental variables directly into the basic DEA model. In this way, the environmental variables are treated as non-discretionary variables[12] (Banker and Morey, 1986), and the optimization program is

$$\min_{\theta\lambda} \theta, st \qquad \begin{aligned} &-\mathrm{yi} + \mathrm{Y}\lambda \geq 0 \\ &-\mathrm{Zi} + \mathrm{Z}\lambda \geq 0 \\ &\theta \mathrm{xi} - \mathrm{X}\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned}$$

[12] The role of the non-discretionary variable is to constrain the comparison set.

where *Z* is the environmental variable vector and Z_0 is the environmental variable of the operator under evaluation.

3. – THE ELECTRICITY DISTRIBUTION INDUSTRY REFORMS IN BRAZIL

3.1. - THE BRAZILIAN ELECTRICITY INDUSTRY EVOLUTION

The BEI has followed the traditional pattern of development of most Latin American countries. In the early age of the industry, most utilities were isolated municipal utilities, with a strong presence of foreign capital[13]. In Brazil, the expansion of the electricity industry took place with almost no government intervention until the 1930s. After 1945, the federal and the state governments played an increasing role in the industry. Public utilities were founded and almost all private utilities were bought by state or federal utilities. After this period, there was a political consensus concerning the public task of the electricity industry[14]. The Federal government has concentrated its operation in the generation firms, while almost all states created their own electricity distribution companies.

The reforms in the BEI started in 1993 with the Act 8631. This Act changed the tariff policy and solved most of the sector's financial impasses. Before this reform, the utilities profitability was guaranteed by cross subsidies. The utilities with better results were supposed to transfer their surplus to a fund, which was used to finance utilities with a worse performance. Therefore, there was no incentive to increase the utility efficiency. After this Act, the tariff passed to be fixed by the regulator and the gains in efficiency could be appropriated by the utility, as profits.

In 1995, the Act 8987 was approved submitting all public services (including the network industries) to competitive bidding. In 1997, the Congress approved the

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[13] See Martin (1966) for an analysis of the history of Brazilian energy industries.

[14] This political consensus took place in almost all the other Latin American countries in this same period.

Law 9427 creating a new regulator (ANEEL), more adapted to the new industry pattern of development. The virtual unbundling of the generation, transmission and distribution function of the current utilities was decided. Finally, in 1998, an independent system operator (ISO) was created, which would be responsible of managing a future wholesale market.

In the second half of the 1990s, the government enforced a very important privatization process. This process was very successful considering the prices paid for privatized utilities[15]. The central government created a very favourable context for the privatization of state owned distribution utilities. The institutional reforms assured the profitability of the privatized utilities in the medium term. The tariffs are determined by the “price cap” system and current tariff levels are fixed for 5 years, allowing the privatized companies to appropriate part of the productivity gains within this period[16].

Nevertheless, the new market-oriented regulatory framework did not consider properly important specificities of the BEI in terms of the institutional complexity and the cost structure. Given these specificities, the new market-oriented regulatory framework was not capable to induce the required investments in the generation segment. Market and regulatory risks remained significant resulting in a low rate of private investment and in the consequent power shortage during the years 2001-2002[17].

The victory of the Workers Party in the 2002 Elections marked a turning point in the energy policy for the gas and power industry. The most important objective of this revision was to provide the Federal Government with new instruments to guarantee the security of the supply. In July 2003, the new government disclosed its proposal for reforming the electricity sector. The new model promoted total separation between the generation and the distribution segments. The current model in Brazil emphasizes competition for the

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[15] This price was in average 50% higher than the minimum price established by the government.

[16] The tariffs were augmented annually in accordance with the Brazilian inflation rates.

[17] Rocha et al (2007) analyzes the return on capital in the Brazilian electricity distribution segment from 1998 to 2005. They conclude that it was systematically negative until 2003.

investment in the generation segment through the centralized bidding process. As far as the distribution segment is concerned, the incentive for efficiency increase is related to the price-cap contract system.

3.2. – PREVIOUS EFFICIENCY AND PRODUCTIVITY STUDIES IN BEI

The efficiency analysis of the distribution companies thus, represents an important research subject since it allows checking the results of the reform process in the Brazilian distribution segment. Efficiency and productivity analysis using a frontier approach in relation to electricity is concentrated on distribution utilities[18]. As a general result, efficiency gains achieved through restructuring and competition of the market (when it occurs) have often not been shared with final users due to the control of the information by the monopolistic companies[19].

Restricting the literature to the recent energy papers, it is observed that they normally adopt one of the two most common efficiency methods: DEA and SFA. Estache et al. (2004) estimate the efficiency of South America's main electricity distribution companies using DEA and SFA in order to obtain information needed for effective regulation making a cross-country benchmarking. They find weak consistency in the efficiency firms' rankings between two approaches, a common result in the apply literature.

Taking into account the single country studies and DEA, one of the first studies to focus on the efficiency measurement of electricity distribution was Weyman-Jones (1991). He analyses the efficiency of 12 electricity distribution utilities in England and Wales prior to reforms and finds a wide efficiency divergence between firms. Forsund and Kittelsen (1998) focus on the differences in efficiency scores and the drivers of efficiency and productivity evolution in the period from 1983-1989 in Norway, finding that most of the productivity change was due to frontier shifts. More recently, Abbott (2006) uses the data

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[18] A good survey of studies on restructuring electricity industries can be seen in Hattori et al. (2005)

[19] In Mota (2004a), producers gained at least half of total net benefits of restructuring and privatization reforms in distribution/supply electricity industry in Brazil between 1995 and 2000.

envelopment analysis (DEA) Malmquist approach to estimate the total factor productivity (TFP) of an Australian electricity supply industry. Australia's electricity supply industry has been through a period of reform over the last 10 years. The purpose of this paper is to evaluate to what degree these reforms have improved the productivity and efficiency performance of the industry. Results indicate that there has been a substantial improvement in the performance of the industry since the mid-1980s.

In Brazil, the interest on efficiency measurement of electricity distribution has recently increased. Two big initiatives can be highlighted: Resende (2002) and Mota (2004b). Resende (2002) measured the performance of a sample of 24 Brazilian distribution utilities in 1997 in order to guide the yardstick competition framework. The author applies the DEA method and measures input as number of employees, transformer´s capacity (in MVA) and network extension (in km); and as outputs, he uses service area (in km2), number of customers, industrial sales (MWh) and non-industrial sales (MWh). The results showed that some firms presented an especially poor performance. The author thus suggests the use of yardstick competition system as a useful way to apply efficiency-inducement mechanisms for Brazilian electricity distribution.

Mota (2004b), on the other hand, tried to measure the electricity distribution performance using the benchmarking approach. Specifically, she benchmarked a sample of 14 privatized Brazilian distribution companies, in the time frame of 1994-2000, comparing them to 72 US investor owned utilities. The comparability between USA and Brazil is due to the comparable area of service which is a relevant factor influencing operating and capital costs of distribution companies. She used two techniques: the DEA and the stochastic frontier. Two alternative input variables were considered: operating and total costs (which include operating and capital costs). When using operating cost, the results showed a positive, but not statistically significant, impact of the Brazilian privatization on technical efficiency. When using total costs model, the results showed a negative and statistically significant, impact of the Brazilian privatization on technical efficiency. The author thus suggests that the result can be associated with an investment surge after privatization process or with a substitution process of capital for labour in the Brazilian distribution sector. Based on these evidences, this author highlights the relevance of establishing standard measures of capital costs for international benchmarking and incentive-based regulation.

4 – Data and Results

In this section we show the results of the Malmquist DEA to show the distribution firms efficiency rankings, but we focus on the analysis of the TFP evolution. With this information, we want to evaluate to what degree the reforms have improved the productivity and efficiency of the industry, that is, the main target of this paper.

4.1 – Data and variables

The data used in this paper consists of a balanced panel of 17 Brazilian electricity distributions over an 8-year period from 1998 to 2005. The data set were constructed on the basis of the Abradee (Brazilian Association of Electricity Distribution Companies) reports. They were complemented by information provided by annual reports of the companies. The 17 companies included in the study deliver about a 54.6% of Brazilian electricity consumption in 2005. Table 1 presents the statistics concerning the companies' size in 2005, specifically, the number of customers, the amount of electricity delivered, service area and region of country covered.

Insert Table 1 about here

Cemig, CPFL and Light – all of them located in the South eastern region of Brazil which concentrates 54.9% of the GDP – are the largest companies in terms of amount of energy delivered. Considering also the criteria of number of customers, this group expands by including Coelba at Bahia State, in the North eastern region of the country. The smallest companies – under both criteria – are Ceb, Cosern, Energipe and Enersul.

In this study, inputs and outputs variables are expressed in physical units. The data available determine the framework within which important features of the operation of distribution utilities can be modelled. The choice is to estimate a distance function because the sample includes private and public firms[20] and because data availability. Having decides about the relationship to be estimated, it is necessary to decide the variables that should be included in the analysis.

Frontier models require the identification of inputs and outputs. Jamasb and Pollitt (2001) provide a useful survey of the use of frontier studies in regulation of electricity distribution. The most frequently used outputs are units of energy delivered, number of customers and size of the service area. The most widely used inputs are number of employees, transformer capacity, network length and operating cost (when using costs as input variables, Jamasb and Pollitt, 2003).

According to Neuberg (1977) both the amount of electricity distributed (in GWh) and the total number of customers served qualify as potential outputs in this sector. As Jamasb and Pollitt (2003) point out, the inclusion of these two output dimensions reflects the spread of demand among the connection points that is generally regarded as a major cost driver. This choice captures the important differences in average consumption levels, as well as between the regional distribution utilities, both of them are included in the sample.

Identifying the inputs, to start off with, it is assumed that the electricity distribution firms use two inputs – labour and capital – to deliver electricity to end users. Besides these inputs, network energy losses are considered as an input. Network losses can be categorized as technical and non-technical losses (measurement errors and unmetred supplies). Reducing costs to consumers requires a reduction in both types of losses and contributes to a reduction in CO_2 emissions. Moreover, the design and maintenance of the network result in losses.

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[20] The estimation of a cost function involves an assumption about firms' behavior, namely profit maximization.

Labour input is estimated as number of employees. Capital input is approximated by the extension of the existing electricity grid (in km)[21]. Losses (in GWh) consist on the difference between the electricity required and the electricity distributed to end users. Finally, service area is unambiguously an exogenous operating characteristic of the firm's environment that contributes to productive efficiency. For this reason, this variable is included in the model as an environmental variable because is beyond the firm's control.

The particular choice of variables made here follows the general consensus found in the current literature. Following the discussion above and the availability of data, the final model for the distance function includes two outputs (energy delivered, number of customers), three inputs (capital, labor and losses) and one environmental variable (service area). Summary statistics of the balanced panel – for the whole of 1998-2005 period - are presented in Table 2; overall, 136 observations are available for estimation. Moreover, sector-wide average of model variables are shown in the Appendix.

Insert Table 2 about here

To get the final model different models were tested. The basic model included two outputs: energy delivered and number of customers, and two inputs: capital and labor. Afterwards, losses were included. Finally, we considered service area as an environmental variable. One can conclude that the model described above is the most convenient for the following facts:

1. Distribution losses are a major source of inefficiency in developing countries (Jamasb et al, 2005) so it must be included. The inclusion of losses as an input lead to worse productivity results for all models.
2. The inclusion of service area as an evironmental variable[22] makes more firms to reach the frontier[23]. Moreover measured efficiency rises

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[21] Network length can either be treated as an output or as input (Estache et al. (2004)). We adopt the second position because we have not other measure of capital input.

[22] Service area is treated as a categorical variable in our DEA model (see Banker and Morey, 1986).

[23] Celpa y Cemat, which are the firms with the largest services area in the sample (see Table 1), reach the frontier when service area is included as environmental factor.

and the dispersion of efficiency across firms is reduced as shown in Table 3 and 4. These further confirm the importance of keeping this variable in the analysis due to it is decisive in explaining efficiency differences across firms.

Insert Table 3 and 4 about here

According to 1, 2 the consideration of the losses as an input and service area as an environmental variable is very important to explain the evolution of the electricity distribution firms. On the other hand, considering energy and customers as outputs allows us to take into account the density as indicated previously.

4.2 – Efficiency ranking

Table 5 presents the efficiency ranking generated through DEA for two years, 1998 and 2005. The DEA results – based on 2 outputs, 3 inputs model and one environmental variable - consider both CRS and VRS assumptions[24].

In 1998 results indicate that with CRS assumptions, 11 companies were relatively efficient. These include Aes-sul, Bandeirante, Celpa, Cemat, Coelba, Coelce, Cosern, CPFL, Elektro, Escelsa and Light. Under the more relaxed VRS assumptions this efficient group enlarges to include Cemig, Energipe and Enersul. In 2005 the DEA outcomes (under CRS strict assumptions) indicate that the efficient group has been reduced to 10 companies because three companies are no longer in the frontier (Coelce, Elektro and Escelsa) while two companies have joined it (Celpe, Cemig). Considering also the DEA-VRS hypothesis, the efficient group expands to 14 (excluding only Celg, Elektro and Escelsa). Therefore 12 of the 17 sample companies present a consistently high performance during the period under analysis.

Insert Table 5 about here

[24] For measuring productivity, a DEA-like linear programming method (DEAP, version 2.1) developed by Coelli (1996) is used to devise the following indexes. From this programming empirical results are obtained.

4.3 – TFP Malmquist Analysis using DEA Methodology

Table 6 below summarizes the mean of TFP – of the whole sample of firms – and its components per year.

Insert Table 6 about here

The last row shows the average computed considering the indices of the whole period. It shows that TFP index records a yearly positive growth of 1.3% in1998-2005 period. Among the TFP components, technical efficiency change shows a bad average performance (-0.8%). The decomposition of this efficiency indicates that the scale efficiency and the pure technical efficiency represent an -0.4% each one. On the other hand, technical change showed a yearly average growth rate of 2.1% in the period.

The average results showed that the productivity evolution of the sample companies in the whole period depended much more on the frontier shift (i.e, technical change) - mainly, due to technological innovations. On the other hand, the scale efficiency indicates an average distancing of the minimum scale efficiency. Then, the pure technical efficiency (the catching up effect) shows that the firms have not improved their behaviour, which allows us to reach to the conclusion that the incentives derived from the reforms in the regulation do not seem to have produced the expected results[25].

It is worth noting that although there was a positive growth rate for the whole period (1998-2005) the opposite is true between 2001-2002 and 2002-2003. In 2001-2002 the total factor productivity reduced by 1.2%; in 2002-2003 the negative performance was even larger, 2.9%. The decreasing performance in 2001-2002 is mainly explained by the contraction of the production frontier (technical change - 2.2%) which is probably related to the electricity shortage in Brazil, occurred in 2001, which affected all the companies in the distribution segment.

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[25] The catching up effect is almost neutral (-0.4%) because some companies improve their efficiency compensating with those that are worsening.

On the other hand, the negative performance in the 2002-2003 period is also explained by the reduction in the companies' efficiency (-1.3%), indicating that they move far away from the frontier. When decomposing this drop in technical efficiency it is possible to highlight that the fall in pure efficiency – probably due to management problems - and scale effect both are the factors behind this negative performance.

Finally, it can be observed that the two last years, between of 2004-2005, the productivity developed favourably. During this last period the pure technical efficiency effect comprises the main factor and contributes to this improvement. This result agrees, in some way or the other, with Rocha et al (2007) that finds out that it is during these years that the firms start to return on positive capital in correspondence with the risk required in the sector.

Table 7 below shows the mean of TFP and its components for each of the firm during the whole of 1998-2005 period.

Insert Table 7 about here

Considering all the firms in the sample, 70.58% of them (12 out of 17) showed an increase in TFP rates. Cemig is the firm that presents the highest yearly growth rate, 12.2%. For this group of firms, almost always technical change is the main component that influences the productivity performance. It is worth noting the performance of Celpe, Coelba and Cosern, which belongs to the same group Iberdrola. These companies showed an average yearly growth rate of 5.2%, 5.5% and 3.1%.

On the other hand, 5 out of 17 firms (Bandeirante, Celg, Celpa, Cemat, Escelsa and Light) presented a negative TFP performance, with an annual average decrease of 3.4%. Light showed the poorest performance, an annual negative growth rate of 5.4%. Behind the result of this company may be the commercial losses due to fraud from the customers.

These companies with negative performance can be divided into two different groups. The first one is composed by Bandeirante, Celpa and Light. For this one the falling productivity is mainly explained by the technical change component. This indicates that the frontier shift was not favourable for them. In the other group, Celg, Cemat, Enersul and Escelsa show a similar profile in terms of a low ratio of amount of electricity distributed by extension of electricity grid and clients served by electricity grid. For these companies, the key component behind the drop in productivity is technical efficiency, denoting that they move far away from the production frontier. By decomposing technical efficiency into pure technical efficiency and scale change, it becomes clear that both factors have equally influenced their negative evolution of TFP.

5 – Main conclusions

The efficiency analysis of the electricity distribution companies is a relevant research subject since it allows to study the impacts of reform process. This paper uses a panel data of 17 firms in the period 1998-2005 to make an efficiency and productivity analysis. The DEA Malmquist approach has been used to calculate the TFP and its decomposition. Some relevant conclusions can be drawn.

Firstly, 11 out of 17 firms (64.7%% of the total) present a moderate performance during the 1998-2005 period. TFP index records a yearly positive growth rate of 1.3% in the whole period under analysis for all firms. However, an important number of firms show a negative behaviour. Generally speaking, these results agree with those of Resende (2002) that show a poor performance of some firms in electricity distribution in Brazil. These results do not contradict those of Mota (2004a) basically because analyzes a different period (1995-2000) and focused on the distribution/supply electricity industry[26].

Secondly, technical change was the main component behind this evolution, with an average growth of 2.1% per year, while technical efficiency presented a

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[26] Mota (2004a) determine the net efficiency impact of restructuring and privatization reforms in distribution/supply electricity industry in Brazil between 1995 and 2000. This paper uses a social cost-benefit analysis to calculate the net effect among consumers, producers and government. Cost reduction was equivalent to a 2.6% of the Brazilian 1994 GDP.

yearly negative performance of -0.8%. The behaviour of the pure technical efficiency seems to indicate that the reforms in the regulation have not led the firms to a more efficient behaviour, generally speaking. The results confirm Mota's (2004b) results who found out a negative and statistically significant impact of the Brazilian privatization on technical efficiency although, when using operating cost, the results showed a positive, but not statistically significant, impact up to the year 2000.

Even though the productivity showed this positive average result, the negative performance of the TFP is also considerable, specifically in the 2001-2002 and 2002-2003 biennium. Both of these negative outcomes may possibly be related to the electricity shortage occurred in 2001. This event has probably altered the general environment where the firms make their decision thus contracting the production frontier and harming the technical efficiency of the firms. However, in the last two years there have been improvements in the behaviour of the TFP of the firms as a whole, even in the pure technical efficiency in the last one of them.

Thirdly, 70.6% of the sample firms have presented an increase in TFP rates. In this respect, Cemig´s performance must be highlighted with a 12.2% average growth rate per year. Celpe and Cosern have also presented significant performances. On the other hand, 6 out of 17 firms showed negative TFP evolution. Light, Celpa and Bandeirante are on this group, even though they are marked as relatively efficient during 1998 and 2005.

As presented in Section 1, only in 2004, after the victory of the Workers Party, the most recent regulatory changes for the Brazillian electricity sector were approved. Since this paper covers the period of 1998-2005 it is quite possible that the results here presented have not been directly influenced by these latest institutional changes. What seems clear is that the electricity shortage, occurred in 2001, has been an exogenous aspect that has, in some way, affected the results showed here.

Future work must therefore expand the data set both in terms of number of firms and the period extension in order to capture if the new regulatory aspects have had an impact on the firm's performance. Special attention must be devoted to examine if the performance of the distribution companies which are vertically integrated significantly differ from those not integrated. Another interesting point regards the use of an output variable measured as number of clients discriminated by type of clients. This measurement flexibility is relevant in that it makes it possible to check the impacts of the recent regulation measures by allowing some big industrial customers to freely choose their electricity distributor irrespectively if the distribution company is or not located in their geographical area.

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Table 1- Size of Sample Companies. 2005

Firm	Sales (GWh)	Number of Customers	Service area	Region of Country Covered
AESSUL	6,293.00	1,038	99,267	South
BANDEIRANTE	7,257.00	1,275	9,644	Southeast
CEB	2,911.10	722	5,783	Midle-West
CELG	6,033.20	1,900	336,871	Midle-West
CELPA	3,875.30	1,298	1,247,703	North
CELPE	6,581.30	2,416	102,745	Northeast
CEMAT	3,474.70	782	906,807	Midle-West
CEMIG	35,756.30	5,952	567,740	Southeast
COELBA	8,535.80	3,787	563,374	Northeast
COELCE	5,668.00	2,297	146,917	Northeast
COSERN	2,668.00	861	53,307	Northeast
CPFL	16,413.00	3,225	90,440	Southeast
ELEKTRO	8,299.50	1,885	120,884	Southeast
ENERGIPE	1,318.90	461	17,419	Northeast
ENERSUL	2,308.10	651	328,316	Midle-West
ESCELSA	4,615.40	1,022	41,241	Southeast
LIGHT	16,078.20	3,765	10,970	Southeast

Table 2 – Sample Summary Statistics

	Variables					
	Outputs		**Inputs**			**Environm.**
	Sales (GWh)	Number of customers	Length of electricity grid (km)	Number of employees	Losses (GWh)	Service Area (km^2)
Mean	8,307.23	1,719.00	68,899.10	2,501.80	2,779.64	273,817.93
Standard Deviation	8,082.68	1,296.05	75,610.23	2,471.40	2,666.55	347,828.85
Minimum	1,318.90	334.43	11,306.00	597.00	669.00	5,783.00
Maximum	35,756.30	5,951.90	379,400.00	11,748.00	14,324.00	1,253,165.00

Table 3 – Differences on Firms Mean Efficiency Score for the whole sample depending on service área

Firms	Without area		With area	
	CRS	VRS	CRS	VRS
AESSUL	1.00	1.00	1.00	1.00
BANDEIRANTE	1.00	1.00	1.00	1.00
CEB	0.79	0.99	0.79	0.99
CELG	0.83	0.85	0.89	0.92
CELPA	**0.87**	**0.91**	**1.00**	**1.00**
CELPE	0.99	0.99	0.99	0.99
CEMAT	**0.64**	**0.80**	**1.00**	**1.00**
CEMIG	0.72	1.00	0.73	1.00
COELBA	0.92	1.00	0.98	1.00
COELCE	0.94	0.96	0.95	0.96
COSERN	0.95	1.00	0.96	1.00
CPFL	0.99	1.00	0.99	1.00
ELEKTRO	0.77	0.82	0.77	0.82
ENERGIPE	0.73	1.00	0.73	1.00
ENERSUL	0.66	0.91	0.85	0.97
ESCELSA	0.76	0.82	0.76	0.82
LIGHT	1.00	1.00	1.00	1.00
Mean	**0.86**	**0.94**	**0.90**	**0.97**

Note:_In both cases model includes two output (customer and sales) and three inputs (labor, network and losses)

Table 4. Differences on Mean and standard deviation of Efficiency Score for the whole sample depending on service area

MODEL	CRS		VRS	
	Mean	Standard deviation	Mean	Standard deviation
without service area	0.86	0.0811	0.94	0.0492
with service area	0.90	0.0590	0.97	0.0324

Note:_In both cases model includes two output (customer and sales) and three inputs (labor, network and losses)

Table 5 – Efficiency Ranking Estimates for 1998 and 2005

FIRMS	1998		2005	
	CRS	VRS	CRS	VRS
AESSUL	1	1	1	1
BANDEIRANTE	1	1	1	1
CEB	0.739	0.935	0.819	1
CELG	0.97	0.994	0.677	0.733
CELPA	1	1	1	1
CELPE	0.972	0.973	1	1
CEMAT	1	1	1	1
CEMIG	0.765	1	1	1
COELBA	1	1	1	1
COELCE	1	1	1	1
COSERN	1	1	0.891	1
CPFL	1	1	1	1
ELEKTRO	1	1	0.857	0.934
ENERGIPE	0.891	1	0.672	1
ENERSUL	0.921	1	0.872	1
ESCELSA	1	1	0.696	0.811
LIGHT	1	1	1	1
MEAN	**0.956**	**0.994**	**0.911**	**0.969**

Table 6 - Malmquist Index Summary of Annual Means

Year	Effch	Techch	Pech	Sech	Tfpch
1999-1998	0.942	1.044	0.981	0.960	0.984
2000-1999	0.986	1.044	0.989	0.997	1.030
2001-2000	0.991	1.060	1.004	0.987	1.051
2002-2001	1.010	0.978	0.985	1.026	0.988
2003-2002	0.987	0.983	0.997	0.990	0.971
2004-2003	1.004	1.023	0.993	1.012	1.027
2005-2004	1.027	1.016	1.023	1.004	1.043
Mean	**0.992**	**1.021**	**0.996**	**0.996**	**1.013**

Table 7 - Malmquist Index Summary of Firm Means

Firm	Effch	Techch	Pech	Sech	Tfpch
AESSUL	1.000	1.021	1.000	1.000	1.021
BANDEIRANTE	1.000	0.970	1.000	1.000	0.970
CEB	1.015	1.007	1.010	1.005	1.022
CELG	0.950	1.021	0.957	0.992	0.970
CELPA	1.000	0.955	1.000	1.000	0.955
CELPE	1.004	1.048	1.004	1.000	1.052
CEMAT	1.000	0.973	1.000	1.000	0.973
CEMIG	1.039	1.079	1.000	1.039	1.122
COELBA	1.000	1.055	1.000	1.000	1.055
COELCE	1.000	1.056	1.000	1.000	1.056
COSERN	0.984	1.049	1.000	0.984	1.031
CPFL	1.000	1.042	1.000	1.000	1.042
ELEKTRO	0.978	1.038	0.990	0.988	1.016
ENERGIPE	0.961	1.051	1.000	0.961	1.009
ENERSUL	0.992	1.023	1.000	0.992	1.015
ESCELSA	0.950	1.034	0.971	0.978	0.981
LIGHT	1.000	0.946	1.000	1.000	0.946
Mean	**0.992**	**1.021**	**0.996**	**0.996**	**1.013**

Appendix.

Sector-wide averages of model variables

Figure 1. Evolution of Total Sales (Gwh).

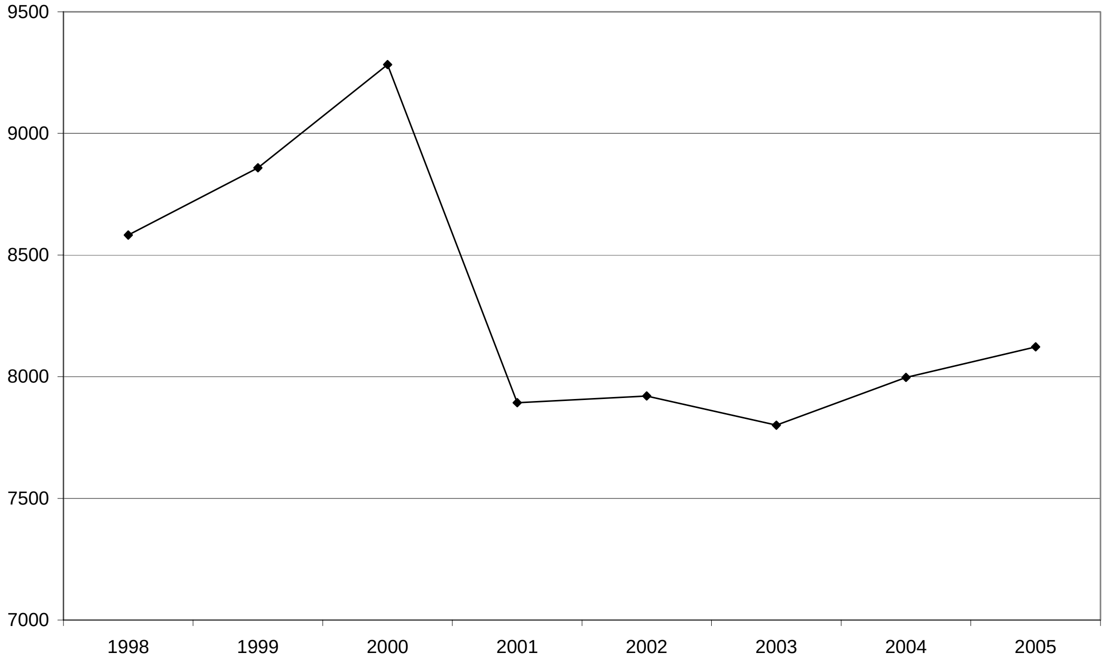


Figure 2. Evolution of Total number of Customers.

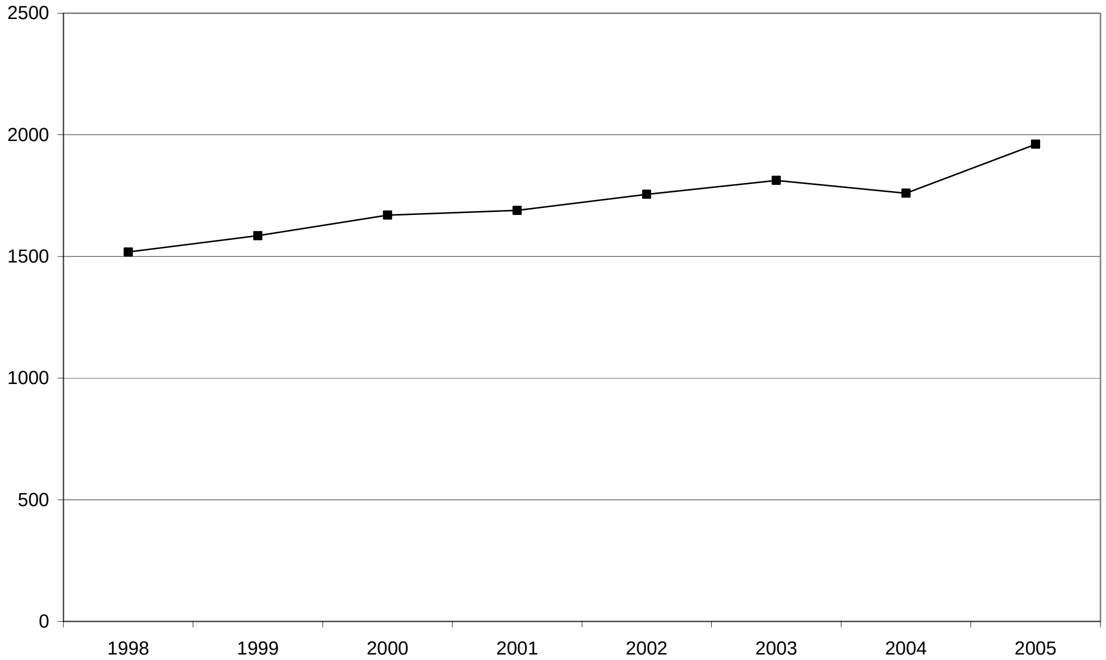


Figure 3. Evolution of Length of electricity grid (km).

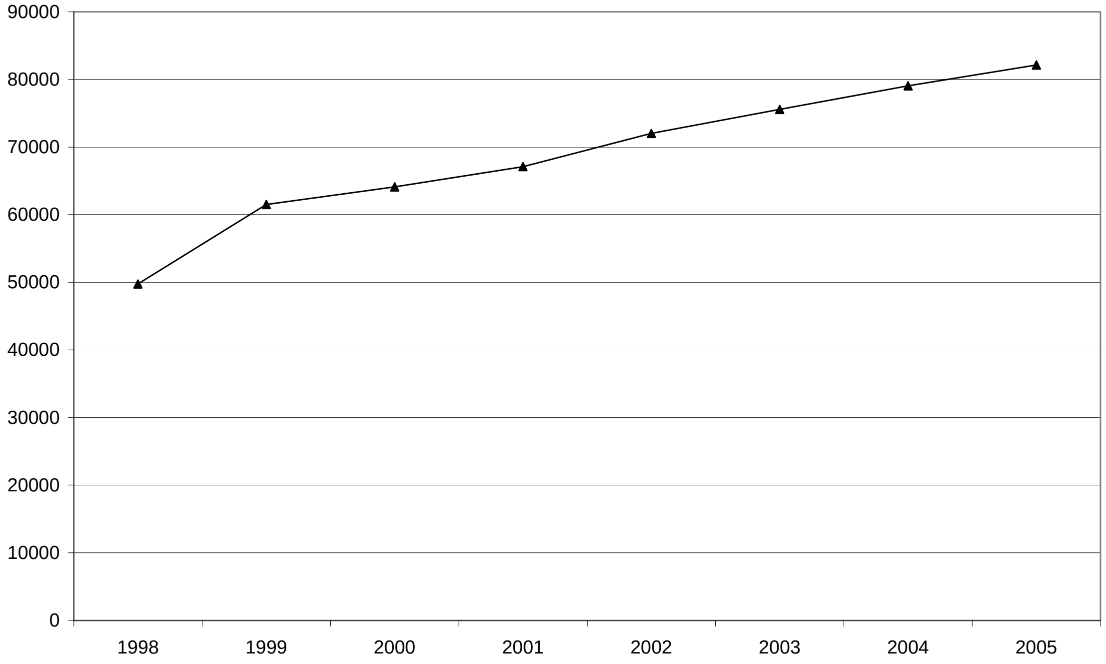


Figure 4. Evolution of Total number of Employees.

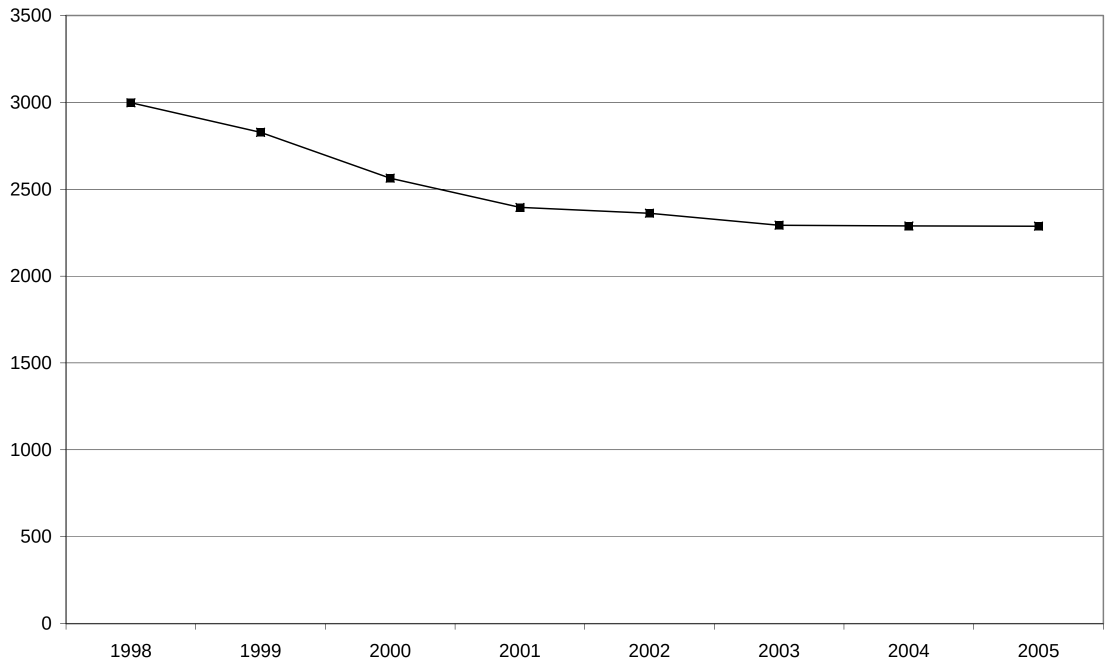


Figure 5. Evolution of Energy Losses (Gwh).

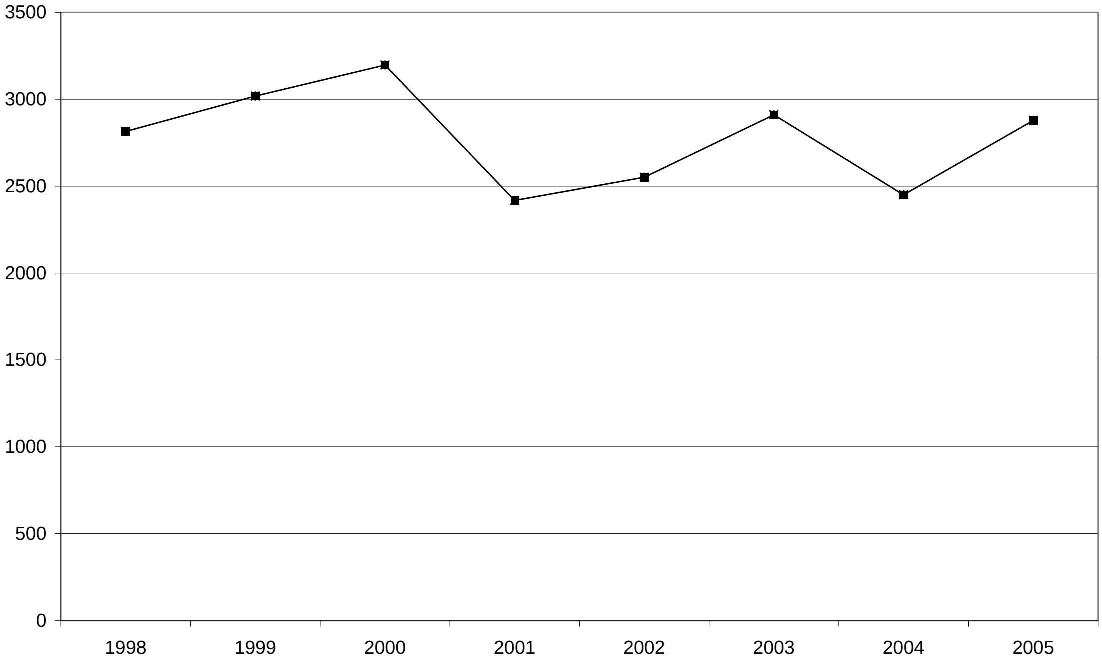
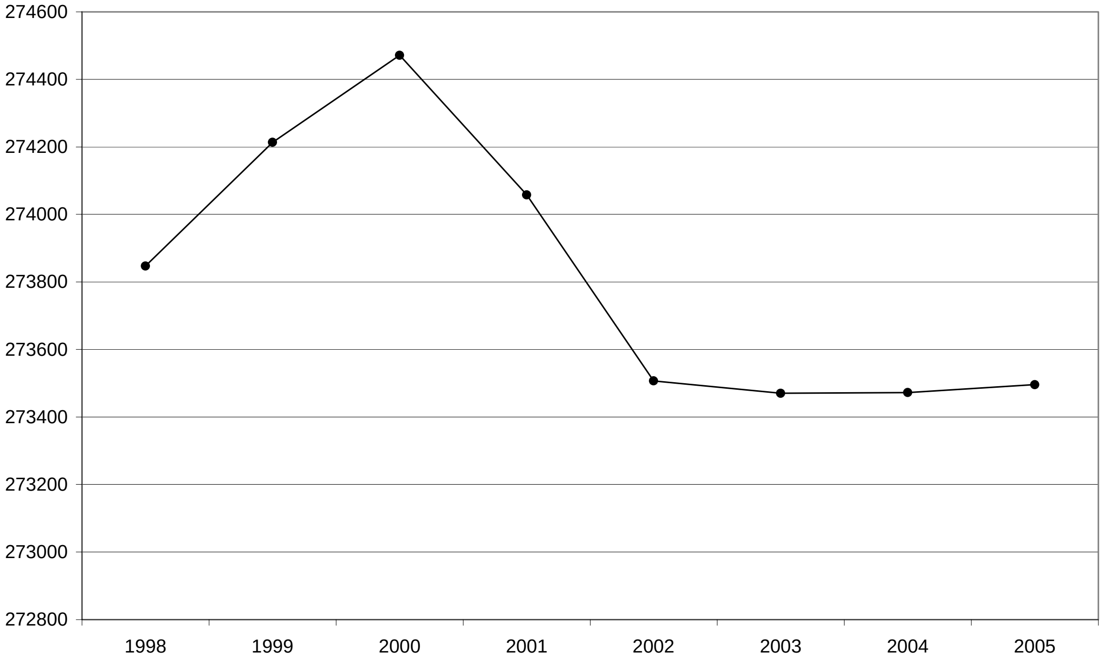


Figure 6. Evolution of Total service area (Km^2).



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