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# Productivity evolution and Scale effects in Brazilian Electricity Distribution Industry. Evidence from 1998-2005 period.

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**Abstract:**

This paper estimates the productivity evolution of the Brazilian electricity distribution industry decomposing it in terms of technical efficiency, scale-efficiency and technical change. This exercise aims to understand one important issue that has not been analyzed in previous papers, that is the impact of firm's size in efficiency and productivity evolution. It employs stochastic frontier analysis on a panel of 18 Brazilian firms from 1998-2005. The results allow us to conclude that company size is an important issue in the evolution of the industry's productivity and, therefore, a key aspect to consider when making decisions affecting the organization and composition of electricity distribution.

**Keywords**: Brazil , electricity distribution, firm size , productivity decomposition. L94

## 1. - INTRODUCTION

In the last three decades, important changes have taken place in the organisation and regulation of the electricity industry in the world. One of the most important features of the reforms was the unbundling of different industry segments. The main idea is to introduce competition in the wholesale market and retail markets, and to have a regulated monopoly in the transmission and distribution sectors. Whenever possible, reforms also broke up horizontally the national distribution companies into several regional monopolies.

Many South American countries have transformed their electricity sector focusing on these principles. In most countries, these changes were associated with the creation of new regulatory agencies responsible for the monitoring of performance of public and private monopolies. The regulatory reforms for monopoly activities have tended to move away from traditional rate of return regulation towards incentive-based regulation models. Incentive regulation can take different forms, but the most common involves the application of some form of price cap regulation.

Until the 1980s, the regulatory framework of Brazilian Electricity Industry (BEI) was mainly characterized by the practice of cross subsidies, central planning of expansion, cost of service practice, and the presence of state-owned firms in all segments. 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 the improvement of 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 tariffs policy using a price cap system.

Efficiency analysis has emerged as a powerful tool to asses the structure of electricity sectors[1], and to help companies and regulators to understand the drivers of productivity. In Brazil, the interest on efficiency and productivity measurement of electricity distribution has recently increased. Ramos-Real et al. (2008) calculate the total factor productivity (TFP) evolution for the period 1998-2005. This paper finds out a moderate positive evolution being technical change the main component of TFP evolution. Results of technical efficiency agree with those of Mota (2004) who found out a negative and statistically significant impact of the Brazilian reforms on technical efficiency and with Resende (2002) that shows a poor performance of some firms in electricity distribution in Brazil.

This paper asses the evolution of productivity in electricity distribution sector in Brazil trying to confirm the results of previous works and focusing in one important issue that have not been analyzed in previous papers that is the impact of firm's size in efficiency and productivity evolution. This exercise aims to analyze the effects of the restructuring and privatization process implemented in the 1990s in the electricity distribution industry in Brazil trying to answer if distribution utilities have an efficient dimension. It employs the stochastic frontier analysis (SFA) through a distance function on a panel of 18 firms from 1998-2005. The estimation decomposes the productivity evolution of the distribution firms in terms of technical efficiency; scale-efficiency and technical progress. Moreover, a further decomposition whereby the technical change (technical progress or technological change) measure could be decomposed into several components.

The paper is organized as follows. The second section provides a presentation of the regulatory framework of Brazilian electricity sector and briefly analyses some empirical

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[1] Some examples can be found in Sanhueza (2003), Giannakis et al (2003),Pombo and Taborda (2006), Abbot (2006) and Estache et al 2008, .For a summary of empirical evidence on electricity distribution efficiency also see Pérez-Reyes and Tovar (in press).

works about this industry in Brazil. The third section presents the data and variables and the fourth section, the methodology used in this work. The fifth section shows the empirical results. Finally, the sixth section presents the main findings of this study.

## 2. – BACKGROUND

This section carries out a brief description of the reform process that has taken place in the industry. The second part describes the results of various studies that have analyzed and evaluated the impact of this process on the Brazilian distribution industry.

### 2.1. - A BRIEF HISTORY OF BRAZILIAN ELECTRICITY INDUSTRY

In the 1980s, the traditional form of organization of the electricity industry has been questioned both in developed and developing countries. This questioning was due to the end of the "virtuous circle" in which the expansion of the electricity industry was accompanied by decreasing tariffs and amelioration of service's quality, as a result of exploitation of scale economies in distribution and generation of electricity. In several developed and developing countries, the public ownership aided this virtuous circle by providing a relatively low-cost source of financing for the industry, enabling the utilities to expand and to improve their services more rapidly.

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 strong presence of foreign capital. 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. Both federal and state governments played an important role in the development of BEI. The Federal government has concentrated its operation in the generation companies, while almost all states created their own electricity distribution companies. This industrial organization and regulation framework was very effective to support the expansion of the BEI[2].

The reforms in BEI started in 1993 with the act 8631. This act changed the tariffs policy and solved most of sector 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 fond, which was used to finance utilities with 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 appropriate by the utility, as profits.

In 1995, the act 8987 was approved submitting all public services (including the network industries) to competitive bidding. In the same year, the Law 9074 created the figure of the Independent Power Producers – IPPs. In addition, the large power consumers (more than 10 Mw) were allowed to buy electricity from any utility, including IPPs, ending with captive markets in the utilities concession areas. In 1997, the congress have approved the Law 9427 creating a new regulator (ANEEL), more adapted to the new industry pattern of development. It has been decided the virtual unbundling of the generation, transmission and distribution function of current utilities. Finally, in 1998 it was created an independent system operator (ISO), which will be responsible to managing a future wholesale market

In the second half of the 1990s, the government enforced a very important privatization process. This process has been very successful if considering the prices paid for privatized utilities[3]. The central government has created a very favorable 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”

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[2] The electricity production has expanded at an annual rate of 9,7% between 1975 and 1980. Over 150 000 Km of transmission lines were built to interconnect many town grids.

[3] This price has been in average 50% higher than the minimum price established by the government.

system and current tariff levels are fixed for the 5 years, allowing the privatized companies to appropriate of part of productivity gains within this period[4]. Nevertheless, the new market-oriented regulatory framework did not properly considered important specificities of the BEI in terms of the institutional complexity and the cost structure. Market and regulatory risks remained significant resulting in a low rate of private investment in the generation segment and in a power shortage in the years 2001-2002.

The victory of the Workers Party in the 2002 elections marked a turning point in energy policy for the gas and power industry. The negative effects of the electricity shortage on the economy and its political impacts impelled the new government to revise the institutional organization and regulatory framework of the electricity sector. The most important objective of this revision was to provide the Federal Government with new instruments to guarantee security of supply. In order to reach this objective, a new model of the electricity sector was proposed based on the following orientations:

i. construction of a more centralized institutional design, reinforcing the role of the Ministry of Mines and Energy;

ii. reduction of the importance of operational competition, with priority given to competition for new investments;

iii. freezing of the privatization process in the sector with the return of the publicly-owned utilities as important players in the expansion of the electricity sector.

In addition to these measures described above, the new model promoted total separation between the generation and distribution segments. The current model in Brazilian emphasizes competition for the investment in the generation segment through the

4 The tarifs will be augmented annually according to the Brazilian inflation rates.

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

## 2.2. – PREVIOUS FINDINGS

In Brazil, the interest on efficiency measurement of electricity distribution has recently increased. Three big initiatives can be highlighted: Resende (2002), Mota (2004) and Ramos-Real et al. (2008). 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 Data Envelopment Analysis (DEA) method and the results showed that some firms presented an especially poor performance. Mota (2004), 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. She used two techniques: the DEA and the SFA. The SFA results showed a positive, but not statistically significant, impact of the Brazilian privatization on technical efficiency.

Ramos-Real et al. (2008) estimated changes in the productivity of the Brazilian electricity distribution sector using 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. The results prove that some firms presented a poorly efficient behaviour and that, in general, the incentives generated in the reform process do not seem to have led the firms to behave in a more efficient manner.

Taking into account key changes in the industry, which led a major restructuring, this paper examines whether the industry structure in the distribution stage has been designed in an efficient way, especially by analyzing the size of distribution companies and its impact on productivity improvements.

## 3 – METHODOLOGY

Productivity is generally defined in economics as the ratio of what is produced to what is required to produce. In a real world, where firms usually use multiple inputs to get multiple outputs, productivity measurement must take this into account using Total Factor Productivity (TFP) measurement. Thus, TFP is a generalization of single-factor productivity measures[5]. TFP growth refers to the change in productivity over time.

There are several approaches to 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 against which each firm is to be compared has to be estimated. It could be done using non-parametric[6] or parametric[7] techniques but, in both cases, some assumption about technology must be done. Both approaches have merits and drawbacks.

In order to measure the productivity change of Brazilian distribution firms we want to estimate the best frontier through the estimation of a distance function because the sample includes private and public firms[8]. On the other hand, in order to estimate it we use a parametric approach to compare with the results of Ramos-Real et al (2008) realized using non parametric techniques but with the same data base[9].

5 Although relatively easy to calculate 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 and would be a more appropriate measurement of productivity.

6 Like DEA and Free Disposable Hull (FDH).

7 It could be linear programming or econometric techniques. Inside the econometric group it could be also distinguished two: deterministic and stochastic frontiers.

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

9 Although several studies compare both methods, the literature is not clear on which approach is superior. A detail 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).

### 3.1 - Measuring and decomposing TFP using Malmquist TFP index

The Malmquist TFP index is chosen to analyze the productivity change and its decomposition. Malmquist productivity indexes were introduced by 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 and 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 follows an input-oriented approach (see Jamasb and Pollit (2000)) as demand for electric distribution services is a derived demand that is beyond the control of utilities and has to be met.

### 3.2. - Malmquist index through SFA

Although lesser than DEA, there are also some studies which have used a parametric (SFA) technique[10] to measure and decompose TFP. SFA was introduced by Aigner, et al (1977) and Meeusen and van deb Broeck (1977), and it is motivated by the idea that

[10] See Kumbhakar and Heshmati (1996), Fuentes et al (2001), Kin and Han (2001) and Orea (2002).

deviations from the production frontier might not be entirely under the control of the agent being studied. Kumbhakar and Lovell (2000) provide a useful revision on this field.

Conversely DEA, SFA does not need the estimation of constant returns on scale (CRS) production technology. Instead the Malmquist productivity index is obtained from the parameters got from a fitted distance function with variable returns to scale. An input distance function can be thought of as a multiple output version of a production frontier and, as we stated before, it characterizes the production technology by looking at a minimal proportional contraction of the input vector, given an output vector

The empirical application of a parametric distance function calls for the definition of an appropriate functional form. It is desirable that the functional form present the following advantages: it must be flexible[11], it must be easy to calculate and, lastly, it must allow imposition of the homogeneity condition. The translogarithmic functional form meets these conditions and this is the reason why we have chosen it. Therefore, we estimate the following stochastic translogarithmic input distance function: [12]

$$\begin{aligned}
-\ln\left(x_{nit}\right) = {} & \alpha_0 + \sum_i^M \beta_i \ln y_{it} + \sum_i^{N-1} \alpha_i \ln x_{it}^* + \frac{1}{2}\sum_i^M \sum_j^M \beta_{ij} \ln y_{it} \ln y_{jt} + \\
& \frac{1}{2}\sum_i^{N-1}\sum_j^{N-1} \alpha_{ij} \ln x_{it}^* \ln x_{jt}^* + \sum_i^M \sum_j^{N-1} \gamma_{ij} \ln y_{it} \ln x_{jt}^* + \lambda_1 T + \lambda_{11} T^2 + \\
& \sum_i^{n-1} \delta_{1i} T \ln x_{it}^* + \sum_i^M \phi_{1i} T \ln y_{it} + v_{it} - u_{it}; \quad con \quad x_{it}^* = x_{it} / x_{nit}
\end{aligned} \tag{1}$$

where $y$ is a vector of $M$ outputs, $x$ is a vector of N factors, T is a time trend, $i$ relates to the *i-th* firm, $\alpha$, $\beta$, $\psi$, $\gamma$, $\rho$, $\theta$ are parameters to be estimated. $v_{it}$ is a symmetrical error terms, iid with a zero average (which represents the random variables un-controllable by the

[11] In order to weaken as much as possible the implications of assuming a particular functional form for the underlying input distance function.

[12] We do it through Frontier, version 4.1, developed by Coelli (1996).

operator) and $u_i$ is a one-sided negative error term (which measures the technical inefficiency of each operator) and is distributed independently of $v_{it}$.

Finally, we follow Battese and Coelli (1992) specification to model the temporal pattern of technical inefficiency, so

$$u_{it} = u_i \exp(-\eta(\tau - T_i)) \qquad (2)$$

where $T_i$ is the last time period in the i[th] panel, $\eta$ is the decay parameter to be estimated, $u_{it}$ are non-negative random variables which are assumed to account for technical inefficiency in production and are taken to be iid as truncations at zero of the N(μ, $\sigma_u^2$) distribution.

The parameters got through the estimation allow us to calculate and decompose TFP change relative to the input distance function estimated in the following way[13]:

$$\ln(\frac{TFP_{i1}}{TFP_{i0}}) = \ln(\frac{TE_{i1}}{TE_{i0}}) + 0.5\left[\left(\frac{\partial \ln D_{i0}}{\partial t}\right) + \left(\frac{\partial \ln D_{i1}}{\partial t}\right)\right] + 0.5\sum_{m=1}^{M}\left[\left(SF_{i0}\ \varepsilon_{mi0} + SF_{i1}\varepsilon_{mi1}\right)\left(\ln y_{ji1} - \ln y_{ji0}\right)\right] \qquad (3)$$

$$\text{with} \quad i = 1, 2, ..., N\ ; t = 1, 2, ..., T$$

where[14]:

Pure Technical Efficiency Change (pech)= $\ln(\frac{TE_{i1}}{TE_{i0}})$;

Technical Change (techch)= $0.5\left[\left(\frac{\partial \ln D_{i0}}{\partial t}\right) + \left(\frac{\partial \ln D_{i1}}{\partial t}\right)\right]$;

Scale Efficiency Change (sech) =$0.5\sum_{m=1}^{M}\left[\left(SF_{i0}\ \varepsilon_{mi0} + SF_{i1}\varepsilon_{mi1}\right)\left(\ln y_{ji1} - \ln y_{ji0}\right)\right]$

The interpretation of these components is the usual one. $TE_{ni}$ is the inverse of the input distance measure and varies between 0 and 1 as required.

13 We follow the general approach outlined in Orea (2002) but adjusted to suit input distance function used here instead output distance function.

14 The multiplication of Pure Technical Efficiency by Scale Efficiency is called Technical Efficiency Change (tech).

The technical change is measured as the mean to technical change obtained in two consecutive periods and is equal to:

$$\left(\frac{\partial \ln D_{it}}{\partial t}\right) = \lambda_1 + 2\lambda_{11}\, t + \sum_{n=1}^{N} \delta_n \ln x_{nit} + \sum_{m=1}^{M} \phi_m \ln y_{mit} \qquad (4)$$

$$with \quad i = 1, 2, ..., N \; ; t = 1, 2, ..., T$$

This procedure results in the decomposition of technical change into three terms: The first two elements of this formula represents the Pure Technical Change (ptc) affecting equally to all companies. The third component is the Non-Neutral Technical Change (nntc) that depends on the production input mix. The last component represents the Scale Augmenting Technical Change (satc) depending on the quantities produced and the production mix.

Finally in order to calculate the scale efficiency change, production elasticity and scale factors are needed. We can calculate productions elasticity, for each output and each observation, through the following expression:

$$\varepsilon_{mit} = \left(\frac{\partial \ln D_{it}}{\partial \ln y_{mit}}\right) = \beta_m + \sum_{m=1}^{M} \beta_{mi} \ln y_{mit} + \sum_{n=1}^{N} \gamma_{ni} \ln x_{nit} + \phi_m t \qquad (5)$$

$$with \quad i = 1, 2, ..., N \; ; t = 1, 2, ..., T$$

In order to obtain scale factor we use:

$$SF_{it} = \frac{(\varepsilon_{it} + 1)}{\varepsilon_{it}} \qquad where \quad \varepsilon_{it} = \sum_{m=1}^{M} \varepsilon_{mit} \qquad (6)$$

$$with \quad i = 1, 2, ..., N \; ; t = 1, 2, ..., T$$

## 4. – DATA AND VARIABLES

The data used in this paper consists of a balanced panel of 18 Brazilian electricity distribution firms 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 18 companies included in the study deliver about a 54.6% of Brazilian electricity consumption in 2005. Table 1 presents the statistics concerning the companie's size in 2005, specifically, the number of customers and amount of electricity delivered.

**Insert table 1 about here**

Cemig, CPFL and Light – all of them located in the Southeastern 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 including so Coelba – at Bahia State, in Northeastern region of the country. The smallest companies – under both criteria – are Ceb, Cosern, Energipe and Enersul.

In this study inputs variables are expressed in physical units. In principle, it is assumed that the electricity distribution firms use two inputs – labor and capital – to deliver electricity to end users. Besides these inputs, network energy losses are considered as an input[15]. Labor input is estimated as number of employees. Capital input is approximated by the extension of the existing electricity grid (in km[16]). Losses (in GWh) consist on the difference between the electricity required and the electricity distributed to end users.

[15] Network losses can be categorized as technical and non-technical losses (measurement errors and un-metered supplies). Dropping costs to consumers requires a reduction in both types of losses and contributes to decrease $CO_2$ emissions. Moreover, the design and maintenance of the network result in losses.

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

Output is defined both as the amount of electricity distributed (in GWh) and the total number of customers served. The inclusion of the number of customers reflects the spread of demand among the connection points that is generally regarded as a major cost driver (Jamasb and Pollit (2003)). This variable also captures the important differences in average consumption levels, as well as between the regional distribution utilities.

Summary statistics of the balanced panel – for the whole 1998-2005 period are presented in Table 2; overall, 136 observations are available for estimation.

**Insert table 2 about here**

## 5. - RESULTS

### 5. 1. – GLOBAL EFFICIENCY RESULTS

Table 3 shows the estimated maximum-likelihood parameters from the input distance function that was estimated by maximum likelihood. It can be seen that all the first order parameters are statistically significant and have the correct sign, which implies that the distance function estimated complies with all the expected theoretical properties. At the sample mean, the conditions of regularity are satisfied; i.e. inputs are non-decreasing and quasi-concave, and outputs are decreasing. The variables have been divided using the geometric mean, therefore the first order coefficients can be interpreted as elasticity. Moreover, the variance parameters, $\sigma^2$ and $\gamma$[17], are statistical significant at a 5% level and the estimated value of parameter $\gamma$ is 0.986; this shows that technical efficiency have an important role to play in explaining efficiency and TFP change. Finally, because the estimate for the parameter $\eta$ is negative the technical efficiency decrease over time, according to the exponential model, defined by equation (2).

**Insert table 3 about here**

[17] The model was estimated using maximum likelihood methods and relied on the parameterizations method proposed by Battese and Corra (1977) who estimated $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$.

Through the distance function parameters estimated technical efficiency of each firm, for each period was assed. The average technical efficiency score[18] in the period for the Brazilian distribution firms are plotted in Figure 1. The most efficient firms are AES-Sul, Bandeirante and Energipe although, as we see in the next section, they are not the best performer in the period where the two latter experience a negative evolution en TFP. On the other hand, the least efficient firms were Cemig, Celg, Cemat, Celpa and Elektro, all of then with a technical efficiency score of 0.6 or less. However, all of then show a good evolution in TFP except Cemat as we will see when analyzing the TFP results.

**Insert Figure 1 About here**

**5.2. – Global evolution of TFP and decomposition**

We can see in Table 4 the summary of TFP industry decomposition by years. The last row shows the average computed considering the indices of the whole period. Results show that TFP index records a yearly positive growth of only a 0.9% in1998-2005 period. Among the TFP components, technical efficiency change shows an important bad average performance (-4%). The decomposition of this efficiency indicates that the pure technical efficiency represents an -3.7%. On the other hand, technical change showed a yearly average growth rate of 4.9% in the period.

**Insert Table 4**

These results confirm, in general, those of Ramos-Real et al (2008) where the productivity evolution of the sample companies in the whole period depended on the frontier shift (i.e, technical change) mainly, due to technological innovations. On the other hand pure technical efficiency (the catching up effect) shows that the firms are moving away from

[18] In order to be brief, we only report average results. However, the annual results are available from the authors upon request.

the efficiency frontier and have not improved their behaviour. Meanwhile, the scale efficiency is neutral for the whole period.

The period evolution shows that TFP is positive in the period 1998-2003 (from 5.6% to 0.6%) mainly because technical change contribution is positive, but TFP is negative in the two last years (see Table 4). The reason is that technical change is declining (although always is positive), and pure technical efficiency is always negative and shows a very bad evolution.

### 5.3. – Analysis of TFP by firms and Scale Economies

In this section it is important to see the non neutral contribution of firm size in TFP evolution. Table 5 shows the TFP decomposition for each firm.

**Insert Table 5 about here**

From this information we can highlight several important facts:

1. Looking at technical change, this component is positive and stronger for the biggest firms in the sample. Cemig, Light, Cpfl with values about 10% of annual average growth. At the same time, for the smallest firms, technical change is less important and sometimes negative as we can see for Energipe, Enersul, Ceb. To analyse this result, we decompose, as we stated before, the technical change measure into a “pure” technical change, non-neutral technical change and scale augmenting technical change. It is observed that scale augmenting explains this fact because is positive and stronger as products grows meanwhile pure technical change does not depend on firm size and non neutral effect is not significant.

It is concluded that frontier shift effects (technical change) are more important for efficiency and productivity as firm size grows. This results are shown in Table 6.

**Insert table 6 about here**

2. Regarding the scale effect on productivity growth several facts can be analysed. Some firms are in the area of scale economies and others in the scale diseconomies one. We can see scale economies firm by firm in the period in Table 7. Obviously, smallest firms are in the first group and the biggest firms in the second one. Only one firm is located in the efficient minimum scale (CELG). The scale effect contribution to TFP for small firms (i.e. Ceb, Celpa, Cemat, Cosern, Enersul with the exception of Energipe), is positive. This means that these companies are moving towards the minimum efficient scale. On the other hand, the biggest firms are moving away from this point[19].

**Insert Table 7**

3. Related to pure technical efficiency, this component is negative for all firms except for Energipe, Bandeirante and Aessul that are those who are in best practice frontier. This component is independent of firm size.

## 6. – CONCLUSIONS

This paper asses the evolution of productivity in electricity distribution sector in Brazil trying to confirm the results of previous works and focusing in one important issue that have not been analyzed in previous papers that is the impact of firm's size in efficiency and productivity evolution. In order to measure the productivity change of Brazilian distribution firms we estimate the best frontier through the estimation of a parametric distance function. The data used in this work consists of a balanced panel of 18 Brazilian electricity distribution firms over an 8-year period from 1998 to 2005.

The period evolution shows that TFP is positive in the period 1998-2003 (from 5.6% to 0.6%) mainly because technical change contribution is positive, but TFP is negative in the two last years. The productivity evolution of the sample companies in the whole period

[19] The value of scale economies of CELG is 1 and, consequently, scale does not affect TFP

depended on the frontier shift (i.e, technical change) mainly, due to technological innovations. On the other hand, pure technical efficiency (the catching up effect) shows that the firms are moving away from the efficiency frontier and have not improved their behaviour. These two findings confirm, in general, those of Ramos-Real et al (2008).

Looking at firm size it is observed two facts. Firstly, technical change is positive and stronger for the biggest firms in the sample explained by scale augmenting effect. It is concluded that frontier shift effects are more important for efficiency and productivity as firm size grows. Secondly, the scale effect contribution to TFP for small firms is positive that means that these companies are moving towards the minimum efficient scale. On the other hand, the biggest firms are moving away from this point.

This exercise aims to analyze the effects of the restructuring and privatization process implemented in the 1990s in the electricity distribution industry in Brazil. From our point of view, these results allow us to conclude that company size is an important issue in the productivity evolution of electricity distribution industry and, therefore, a key aspect to consider when making decisions affecting the organization and composition of this industrial sector.

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Table 1- Size of Sample Companies

| Firm | Sales (GWh) | Number of Customers | Region of Country Covered |
|---|---|---|---|
| **AESSUL** | 6,293.00 | 1,038 | South |
| **BANDEIRANTE** | 7,257.00 | 1,275 | Southeast |
| **CEB** | 2,911.10 | 722 | Midle-West |
| **CELG** | 6,033.20 | 1,900 | Midle-West |
| **CELPA** | 3,875.30 | 1,298 | North |
| **CELPE** | 6,581.30 | 2,416 | Northeast |
| **CEMAT** | 3,474.70 | 782 | Midle-West |
| **CEMIG** | 35,756.30 | 5,952 | Southeast |
| **COELBA** | 8,535.80 | 3,787 | Northeast |
| **COELCE** | 5,668.00 | 2,297 | Northeast |
| **COSERN** | 2,668.00 | 861 | Northeast |
| **CPFL** | 16,413.00 | 3,225 | Southeast |
| **ELEKTRO** | 8,299.50 | 1,885 | Southeast |
| **ENERGIPE** | 1,318.90 | 461 | Northeast |
| **ENERSUL** | 2,308.10 | 651 | Midle-West |
| **ESCELSA** | 4,615.40 | 1,022 | Southeast |
| **LIGHT** | 16,078.20 | 3,765 | Southeast |

Table 2 – Sample Summary Statistics

| | Variables | | | | |
|---|---|---|---|---|---|
| | Outputs | | Inputs | | |
| | Sales (GWh) | Number of customers | Length of electricity grid (km) | Number of employees | Losses (GWh) |
| **Mean** | 8,307.23 | 1,719.00 | 68,899.10 | 2,501.80 | 2,779.64 |
| **Standard Deviation** | 8,082.68 | 1,296.05 | 75,610.23 | 2,471.40 | 2,666.55 |
| **Minimum** | 1,318.90 | 334.43 | 11,306.00 | 597.00 | 669.00 |
| **Maximum** | 35,756.30 | 5,951.90 | 379,400.00 | 11,748.00 | 14,324.00 |

Table 3 – Input Distance Function parameter estimates

| Variable | coefficient | standard-error | t-ratio |
|---|---|---|---|
| **cte** | 0.440 | 0.044 | 10.098 |
| **deliverd energy (MWh)** | -0.237 | 0.074 | -3.206 |
| **customers (nº)** | -0.545 | 0.143 | -3.818 |
| **network lenght (km)** | 0.275 | 0.032 | 8.520 |
| **Labor (nº)** | 0.468 | 0.041 | 11.337 |
| **Losses (Mwh)** | 0.256 | 0.038 | 6.688 |
| **t** | 0.049 | 0.008 | 5.834 |
| **delivered energy sq** | -0.191 | 0.193 | -0.993 |
| **delivered energy x customers** | 0.344 | 0.209 | 1.647 |
| **network lenght x delivered energy** | -0.034 | 0.071 | -0.487 |
| **labor x deliverd energy** | 0.273 | 0.121 | 2.259 |
| **lossesx delivered energy** | -0.239 | 0.140 | -1.700 |
| **delivered energy x t** | -0.005 | 0.015 | -0.320 |
| **customers sq** | -0.941 | 0.338 | -2.788 |
| **network lenght x customers** | -0.075 | 0.082 | -0.917 |
| **labor x customers** | -0.118 | 0.149 | -0.794 |
| **losses x customers** | 0.193 | 0.173 | 1.113 |
| **customers x t** | 0.073 | 0.016 | 4.503 |
| **network lenght sq** | 0.032 | 0.044 | 0.729 |
| **network lenght x labor** | -0.088 | 0.062 | -1.414 |
| **network lenght x losses** | 0.056 | 0.068 | 0.831 |
| **network lenght x t** | 0.006 | 0.009 | 0.640 |
| **labor sq** | 0.161 | 0.160 | 1.008 |
| **labor x losses** | -0.073 | 0.113 | -0.650 |
| **labor x t** | 0.038 | 0.019 | 1.965 |
| **losses sq** | 0.017 | 0.077 | 0.219 |
| **losses x t** | -0.044 | 0.017 | -2.526 |
| **t sq** | -0.009 | 0.004 | -2.089 |
| **sigma-squared** | 0.290 | 0.169 | 1.983 |
| **gamma** | 0.986 | 0.009 | 111.200 |
| **mu** | is restricted to be zero | | |
| **eta** | -0.126 | 0.024 | -5.275 |

Figure 1 Brazilian distributions firms' average Technical Efficiency

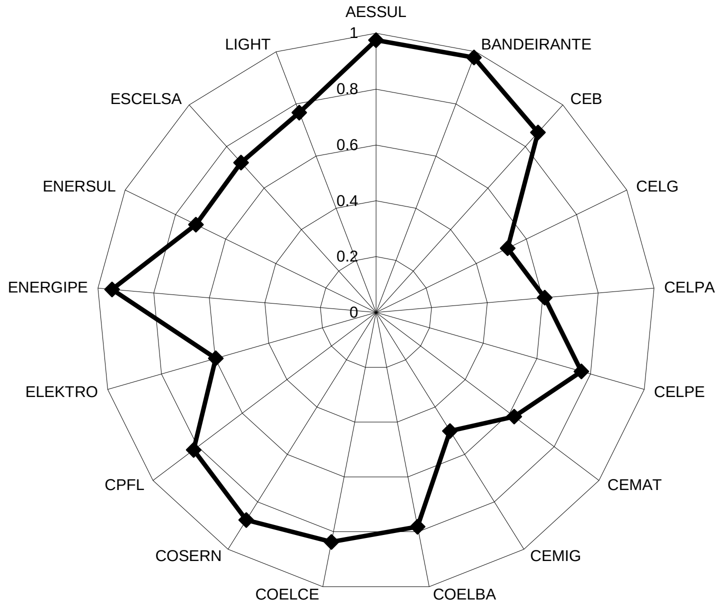

Table 4 – Malmquist Index. Summary of years' means

| | TECHCH | TECH | Pure TECH | SE CH | TFPCH |
|---|---|---|---|---|---|
| **1998-1999** | 1.074 | 0.981 | 0.975 | 1.006 | 1.056 |
| **1999-2000** | 1.064 | 0.981 | 0.972 | 1.009 | 1.046 |
| **2000-2001** | 1.057 | 0.945 | 0.968 | 0.976 | 1.002 |
| **2001-2002** | 1.050 | 0.973 | 0.964 | 1.009 | 1.024 |
| **2002-2003** | 1.040 | 0.965 | 0.959 | 1.006 | 1.006 |
| **2003-2004** | 1.032 | 0.934 | 0.953 | 0.979 | 0.965 |
| **2004-2005** | 1.024 | 0.942 | 0.947 | 0.994 | 0.967 |
| **Mean** | **1.049** | **0.960** | **0.963** | **0.997** | **1.009** |

Table 5 – Malmquist Index. Summary of firms' means

| | TECHCH | TECH | Pure TECH | SE CH | TFPCH |
|---|---|---|---|---|---|
| **AESSUL** | 1.013 | 0.998 | 0.997 | 1.001 | 1.011 |
| **BANDEIRANTE** | 1.035 | 0.958 | 0.997 | 0.960 | 0.992 |
| **CEB** | 0.994 | 0.994 | 0.982 | 1.012 | 0.988 |
| **CELG** | 1.084 | 0.918 | 0.919 | 0.999 | 1.002 |
| **CELPA** | 1.047 | 0.960 | 0.937 | 1.024 | 1.008 |
| **CELPE** | 1.073 | 0.963 | 0.966 | 0.997 | 1.036 |
| **CEMAT** | 1.011 | 0.973 | 0.940 | 1.035 | 0.985 |
| **CEMIG** | 1.158 | 0.902 | 0.913 | 0.988 | 1.059 |
| **COELBA** | 1.115 | 0.953 | 0.969 | 0.983 | 1.067 |
| **COELCE** | 1.080 | 0.971 | 0.978 | 0.993 | 1.051 |
| **COSERN** | 1.001 | 0.998 | 0.984 | 1.015 | 0.999 |
| **CPFL** | 1.097 | 0.973 | 0.975 | 0.998 | 1.069 |
| **ELEKTRO** | 1.068 | 0.936 | 0.935 | 1.001 | 1.004 |
| **ENERGIPE** | 0.964 | 0.935 | 0.993 | 0.941 | 0.897 |
| **ENERSUL** | 0.998 | 0.967 | 0.958 | 1.009 | 0.965 |
| **ESCELSA** | 1.020 | 0.957 | 0.959 | 0.998 | 0.977 |
| **LIGHT** | 1.087 | 0.967 | 0.967 | 1.000 | 1.054 |
| **Mean** | **1.049** | **0.9597** | **0.963** | **0.997** | **1.009** |

Table **6 Technological Change decomposition by firms**

| | TECHCH | Pure TECHCH | Non Neutral TECHCH | Scale Augmenting TCCHCH |
|---|---|---|---|---|
| **AESSUL** | 1.0134 | 1.0487 | 0.9897 | 0.9750 |
| **BANDEIRANTE** | 1.0349 | 1.0487 | 0.9820 | 1.0044 |
| **CEB** | 0.9938 | 1.0487 | 0.9989 | 0.9462 |
| **CELG** | 1.0840 | 1.0487 | 1.0192 | 1.0160 |
| **CELPA** | 1.0472 | 1.0487 | 1.0114 | 0.9870 |
| **CELPE** | 1.0734 | 1.0487 | 0.9906 | 1.0341 |
| **CEMAT** | 1.0112 | 1.0487 | 1.0133 | 0.9492 |
| **CEMIG** | 1.1577 | 1.0487 | 1.0146 | 1.0941 |
| **COELBA** | 1.1151 | 1.0487 | 1.0069 | 1.0594 |
| **COELCE** | 1.0802 | 1.0487 | 1.0037 | 1.0276 |
| **COSERN** | 1.0007 | 1.0487 | 0.9920 | 0.9600 |
| **CPFL** | 1.0967 | 1.0487 | 0.9965 | 1.0514 |
| **ELEKTRO** | 1.0683 | 1.0487 | 1.0030 | 1.0166 |
| **ENERGIPE** | 0.9644 | 1.0487 | 0.9956 | 0.9199 |
| **ENERSUL** | 0.9976 | 1.0487 | 1.0061 | 0.9427 |
| **ESCELSA** | 1.0200 | 1.0487 | 0.9987 | 0.9726 |
| **LIGHT** | 1.0874 | 1.0487 | 0.9778 | 1.0610 |
| **Mean** | **1.0486** | **1.0487** | **0.9999** | **0.9999** |

Table 7 Scale Economies evolution by firms

| Firms | Scale Economies |
|---|---|
| **AESSUL** | 1.483899 |
| **BANDEIRANTE** | 1.539360 |
| **CEB** | 3.076883 |
| **CELG** | 1.004043 |
| **CELPA** | 1.633932 |
| **CELPE** | 0.937203 |
| **CEMAT** | 2.639134 |
| **CEMIG** | 0.750845 |
| **COELBA** | 0.771375 |
| **COELCE** | 0.909045 |
| **COSERN** | 1.624996 |
| **CPFL** | 0.946164 |
| **ELEKTRO** | 1.109348 |
| **ENERGIPE** | 4.849903 |
| **ENERSUL** | 2.352069 |
| **ESCELSA** | 1.756548 |
| **LIGHT** | 0.980463 |