EMPIRICAL ESSAYS IN THE ECONOMICS OF REGULATION

By

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To
Ethevaldo and Arlete
Rita, Leonardo, and Fernanda

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EMPIRICAL ESSAYS IN THE ECONOMICS OF REGULATION

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Reform processes undertaken on network industries have encompassed unbundling, privatization, introduction of market-oriented regimes for their competitive segments, and implementation of a new regulatory framework for the remaining segments with natural monopoly characteristics. The new regulatory framework has involved the creation of independent regulatory bodies and the incorporation of theoretical advances from the economics literature on incentive regulation, under the ultimate objective of providing the conditions and incentives for efficiency improvement and for the possible achievement of second best prices. This dissertation adds to the literature on the impacts of the restructuring measures implemented and contains three empirical essays on the reforms accomplished in the Brazilian electricity sector.

In Chapter 2, information on stock market reactions to regulatory announcements are employed to investigate the level of consistency and predictability of decisions taken by the Brazilian electricity sector regulator and to identify the extent the aforementioned regulatory body has been able to act independently and to balance multiple interests in regulation. The findings indicate that the regulator's decisions have not favored a single interest group. The evidenced unpredictability of the regulatory agency's decisions suggests the need for

improvements in the regulatory discussion process, with the adoption of measures to increase the transparency and to promote more substantive public hearings. Additionally, the study shows that the need to provide incentives for new investments has played a significant role in the regulatory process. The estimates indicate that regulatory decisions accounted for roughly 12% of the difference in performance of the sample securities with respect to the market index.

The Chapter 3 examines the impact of privatization and incentive regulation on firms' performance in the period of 1998 to 2003. Evidence indicates performance improvement after the implementation of sector reforms, with both privatized and public companies reducing the efficiency gap with respect to companies that were privately owned before the reforms. The results show that privatized firms responded more aggressively than public firms to the new incentives brought by price-cap regulation, and suggest that the high performance improvement experienced by privatized firms did not come from mere reduction in costs brought by deterioration in the quality of service. The findings also indicate a possible strategic behavior associated with the periodic aspect of price-cap regulation, as well as to cost shifting implemented by companies that operate in the electricity generation segment.

The Chapter 4 is motivated by the increasing use of the model company approach to determine electricity distribution tariffs in Latin America, despite the criticisms made to the method's subjectivity and obscurity. The study examines whether the use of the engineering approach in the Brazilian electricity distribution sector periodic tariff review enabled the attainment of the welfare maximizer regulator's rate setting objectives, by comparing the method's implied performance scores to efficiency measures provided by economic benchmarking approaches. Results show that some firms, mainly the ones serving more affluent consumers, operating in more densely populated areas and having a lower proportion of electricity delivered to industrial customers, received substantially lower repositioning indexes than the economic benchmarking methods would recommend, pointing to a possible violation of firms' break-even constraints. The findings also reveal that significantly higher repositioning indexes might have been given to companies with the opposite characteristics, negatively affecting the incentives for further productivity improvements, as some of the possibly benefited companies do not appear in the top ten of the benchmarking efficiency rankings.

CHAPTER 1
INTRODUCTION

Network industry reforms recently implemented have involved unbundling, privatization, introduction of market-oriented regimes for their competitive segments, and implementation of a new regulatory framework for the remaining segments with natural monopoly characteristics.

One of the features of the new regulatory framework has been the emergence of autonomous regulatory bodies. The associated increase in regulatory discretion, however, has raised concerns over the possible influence of interest groups on regulatory outcomes, strengthening the debate over the pattern of government intervention in business, represented by two main opposing theories: the “public interest” approach, which asserts that the government acts to lessen or eliminate the inefficiencies engendered by market failure; and the “capture” or “interest group” approach, which argues that the government acts to transfer wealth between interest groups in an effort to maximize political support. Examining the actual behavior of regulatory agencies, in this context, constitutes an empirical question, addressed by Sawkins (1996), Dnes, Kodwani, Seaton, and Wood (1998), and Dnes and Seaton (1999) on the perspective of the energy and water industries in United Kingdom.

The new regulatory design has also comprised the incorporation of theoretical advances from the economics literature on incentive regulation, notably the implementation of incentive mechanisms, such as the price-cap method. In case, the firm and its managers are the residual claimants on production cost reductions, and bear the disutility of increased managerial effort (Joskow, 2005). As a result, the conditions and incentives for efficiency improvement and for the possible achievement of second best prices are settled. However, whether price-cap regulation effectively leads to efficiency improvement also constitutes an empirical question.

This dissertation examines these questions in the context of the reforms accomplished in the Brazilian electricity sector. The reforms began in 1995. While constitutional amendments abolished the public monopoly over infrastructure industries and allowed foreign companies to bid for public concessions, the Law 8,987/95 (General Law of Concessions) set the stage for the beginning of the privatization process, represented by the auctions of Escelsa in 1995 and Light in 1996. By the end of 2000, a total of 20 distribution companies had been privatized.

In addition, the implementation of a new regulatory framework involved the establishment of an independent regulatory agency (ANEEL) in late 1996 and the institution of a new model for the electricity sector in 1998. The model focused on privatization and unbundling of generation, transmission and distribution assets, gradual transition to a competitive generation environment in nine years, creation of a wholesale power market, operation of the transmission network by an independent operator, and use of the price-cap regime to regulate distribution tariffs, replacing the previous cost of service system. Price-cap regulation was implemented through the signature of new concession contracts, which took place from 1998 to 2000, and scheduled the first tariff review for after five (for contracts signed in 1998) or four years. As a result, 61 companies were submitted to a tariff review process from April/2003 to February/2006.

The analysis is performed in Chapters 2 to 4. The Chapter 2 ("An Empirical Assessment of the Regulator's Performance in the Brazilian Electricity Sector") uses information on stock market reactions to regulatory announcements to investigate the level of consistency and predictability of decisions taken by the Brazilian electricity sector regulator, and to identify the extent the aforementioned regulatory body has been able to act independently and to balance multiple interests in regulation. The investigation improves upon previous studies by focusing in the context of a developing country, where the interests are presumably more pronounced, and by employing an identification strategy that explicitly accounts for the possibility of event anticipation. In addition, the study sheds light on the debate over the possible capture of Brazilian regulatory agencies.

The Chapter 3 ("Privatization, Incentive Regulation, and Efficiency Improvements in the Brazilian Electricity Distribution Industry") concentrates on the effectiveness of the price-cap incentive mechanism issue. The study examines the impact of privatization and incentive regulation on performance of Brazilian electricity distribution companies in the period of 1998 to 2003, employing a Stochastic Frontier Approach (SFA) that controls for heterogeneity in operating conditions, influence of macroeconomic factors, and random shocks.

The investigation evaluates the efficiency evolution and the productivity gains that occurred in the period, checks for difference in performance between public and private firms, and looks at the possibility of efficiency catch-up. It also examines whether vertically integrated firms might be behaving strategically, shifting costs from unregulated to regulated activities, and whether efficiency changes are associated with variations in service quality.

The Chapter 4, entitled "The Assessment of Firms' Efficiency in Periodic Tariff Reviews: An Evaluation of the Reference Utility Approach," is an extension of the previous one. The obtained SFA efficiency estimates and measures of firms' productivity improvements, along with efficiency measures provided by an alternative benchmarking technique (Data Envelopment Analysis), are employed to examine the results derived from the use of the Reference Utility approach at the distribution companies' first periodic tariff review.

The study is motivated by the increasing use of the reference utility model to determine electricity distribution tariffs in Latin America, despite the criticisms made to the method's subjectivity and obscurity. The analysis checks whether the methodology has enabled the attainment of the welfare maximizer regulator's rate setting objectives, and is based upon the reasoning that substantial (and consistent) divergences in the Model Company's implied performance scores, relative to efficiency measures provided by economic benchmarking approaches, reflect deficiencies in the engineering method's application.

In sequence, the investigation checks for the possible causes of the divergences found, not only exploring the predictions of the same interest group theory of regulation employed in the second chapter, but also accounting for the fact that the regulator's decisions were taken in an incomplete and imperfect information context. In case, it is examined the possibility of flaws in the engineering cost parameters employed to estimate the efficient costs and the potential use of some of the available data as signals for firms' profitability and cash flow availability, as a subsidy for the regulator's decisions regarding the distribution of productivity gains among stakeholders.

The three chapters mentioned above are self-contained, presenting the results obtained and the corresponding conclusions. Nonetheless, the main results and conclusions evidenced in the three studies that compound this dissertation are outlined in Chapter 5, along with directions for future research.

CHAPTER 2
AN EMPIRICAL ASSESSMENT OF THE REGULATOR'S PERFORMANCE IN THE BRAZILIAN ELECTRICITY SECTOR

Introduction

The analysis of regulatory impacts provides insights into the level of predictability and consistency of regulatory actions, and is essential if we are to understand how regulatory processes and regulatory decisions affect infrastructure performance. The subject's importance has increased with the emergence of autonomous regulatory bodies, in the context of network industry reforms recently implemented, as the associated boost in regulatory discretion has raised concerns over the possible influence of interest groups on regulatory outcomes, although the role of special interests within predecessor government ministries was not insignificant, and probably less transparent.

The issues raised by regulation continue a debate over the pattern of government intervention in business, which has long been carried out in the fields of economics and political science and resulted in two main opposing theories: the "public interest" approach, which asserts that the government acts to lessen or eliminate the inefficiencies engendered by market failure, serving as an impartial referee that aims to maximize social welfare; and the "capture" or "interest group" approach, which argues that the government acts to transfer wealth between interest groups in an effort to maximize political support.[1] Recent agency theoretical models

[1] According to Stigler (1971), regulators are self-interest maximizers and stakeholders face costs of organization and information. Consumers, being dispersed and having less at stake, face higher costs of organization than producers and usually do not have the required incentives to spend the necessary resources to become informed. Consequently, the prediction was that the producer interest would win the bidding for the services of a regulatory agency. Stigler's formulation brought theoretical foundation to the "producer protection" view that characterizes the capture theory of regulation, based on the accumulating evidence of empirical research done before the 1970s. The Stigler's argument, however, was further developed by Peltzman (1976), who posited that regulatory agencies would not exclusively serve a single economic interest. Utility-maximizing regulators would allocate benefits across interest groups optimally, attempting to equate political support and opposition at the margin. Peltzman's contribution helps explain the location of policy in the competitive price to the monopoly price spectrum. Consumers who spend a larger share of their income on a good have a higher incentive to participate in the regulatory process and should drop more

further developed the interest group theory by explicitly recognizing both the existence of informational asymmetries and the principal-agent relationship which exists between the Congress (or the Government) and their delegates in regulatory agencies.[2]

The possibility that the regulator may favor specific interest groups underscores the need to devise regulatory frameworks incorporating a system of checks and balances. However, to determine how regulatory processes and decisions affect sector performance, it is necessary to assess the actual behavior of the regulatory agencies. The present study uses information on stock market reactions to regulatory announcements to investigate the level of consistency and predictability of decisions taken by the Brazilian electricity sector regulator, and to identify the extent the aforementioned regulatory body has been able to act independently and to balance multiple (and often conflicting) interests in regulation.

With respect to network industries, the empirical research conducted to date focused in the United Kingdom's context. While Sawkins (1996) analyzed the performance of the water sector regulator (Ofwat), both Dnes, Kodwani, Seaton, and Wood (1998) and Dnes and Seaton (1999) concentrated on the behavior of the electricity industry's regulatory agency (Offer). In all these studies, the similar findings that no interest group had been systematically favored led to the conclusion that the regulatory bodies were performing their duties reasonably well.

The conclusion of "balanced" decision-making, however, was drawn on the basis of securities' abnormal returns evidenced at the moment of the regulatory announcements. Studies neglected the possibility that the findings were actually reflecting a change in market

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votes for the politician in response to a price rise. Therefore, goods with a high share in the consumers' budget are more likely to have prices close to the competitive price.

[2] See Laffont and Tirole (1993), and Armstrong and Sappington (2003), for contributions on the subject.

expectations.[3] The present research attempts to correct for this flaw by also looking at the significance of the cumulative abnormal returns in the period before the event's disclosure. Thus, when there is evidence of an early incorporation of the event's effect, the regulatory announcement's impact is based on a computed measure of the event's overall effect.

The present investigation also distinguishes from the previous ones by focusing in the context of a developing country, where the different interests in regulatory outcomes seem to be more pronounced. In addition to both Brazilian firms and consumers having a higher incentive to participate in the regulatory process than their counterparts in Great Britain,[4] it may be argued that the Brazilian Government exerts a higher pressure on the regulator to keep tariffs at low levels than a Government in a developed country, by virtue of the memories of the recent hyperinflation period and the consequent still strong concern with the effect of tariff increases on inflation. Moreover, Brazil faces an acute need to expand network access (provide universal service) and to increase the amount of energy distributed, to avoid energy shortages in the near future and promote economic growth. The resulting greater necessity to provide incentives for (private) investments in the sector should be reflected in a higher pressure on the regulator along these lines in Brazil than in Great Britain.

[3] A finding of negative and significant abnormal returns at the exact moment a regulatory announcement is made, for example, may not indicate that the decision affected firms' value negatively, but, on the contrary, that the decision was not as good to firms as the market was expecting. Thus, when a significant abnormal return is found, one has to check for the possibility of event anticipation. If this possibility is confirmed, the conclusion regarding the event's impact has to be taken on the basis of the event's overall effect.

[4] Brazilian firms face higher regulatory and country risks than firms in Great Britain, which impacts the necessity to mitigate the possibility of not getting a rate of return that covers their correspondent higher cost of capital. The affirmative regarding Brazilian consumers, on the other hand, comes from the fact that they are poorer. Since the income elasticity for electricity is less than one, electricity is a greater share of the budget of poor people than of rich people. Thus, in case of a tariff increase, poor consumers experience a higher percentage change in their cost of living than those who are more affluent. Therefore, poor consumers (or consumers in poor countries) have a greater incentive than rich consumers (or consumers in rich countries) to become informed and participate in the regulatory process.

The Brazilian electricity sector's regulatory framework has been critically explored and analyzed relative to international experience,[5] resulting in some policy changes. Nevertheless, there remains a debate over the regulator's possible capture by the industry,[6] indicating a need for further investigations of the regulatory agency's performance.[7] The present study attempts to fill this gap.

The paper's contributions to the literature are thus the following: (a) it extends the event-study methodology employed in previous studies, by explicitly recognizing the need to account for the possibility of event anticipation; (b) it is, to our knowledge, the first empirical assessment of a regulatory agency performance in the context of a developing country, where the interests are presumably more pronounced; (c) it examines the level of consistency and predictability of decisions taken by the Brazilian electricity sector regulator; and (d) it sheds light on the debate over the possible capture of Brazilian regulatory agencies.

The following section presents the characteristics of the Brazilian electricity industry and describes the reforms implemented in recent years. Section 3 explains the methodology employed and Section 4 outlines the data set. Section 5 presents and interprets the results

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[5] The main initiative on this respect was represented by Brown and de Paula's reports (2002, 2004) prepared under the World Bank's PPIAF Project for Brazil Power Sector, Task 4: "Strengthening of the Institutional and Regulatory Structure of the Brazilian Power Sector". The first report, issued in December 2002, analyzed the state of institutional arrangements in electricity regulation right after the energy crisis and proposed specific recommendations for strengthening the regulatory structure. The second report was prepared in July 2004 and reviewed the previous recommendations in light of the regulatory changes occurred in the period, detailed in the following section. The vast majority of the recommendations made were effectively implemented by the Government (Ministry of Mines and Energy) and the regulatory agency (ANEEL).

[6] The debate was reinforced when the Government submitted a proposal to the Congress to better define the role of the regulatory agencies, in September of 2003. The proposal, which is still pending in the Congress, contains elements that limit regulatory agencies' independence, such as establishing performance contracts and defining ombudsman duties. The justification that accompanies the proposal refers to the need of social control over the job done by all infrastructure regulatory agencies.

[7] Based on a literature review, Pires and Goldstein (2001) appears to be a unique study on the subject. The authors evaluate the performance of the regulatory agencies responsible for the regulation of the telecommunications, electricity and oil sectors. It is not an empirical study, however.

obtained, while Section 6 portrays the robustness checks performed. The final section provides concluding observations.

Institutional Background

In event studies, the interpretation of results requires a reasonable understanding of the context in which the regulatory initiatives were undertaken.[8] In Brazil, fluvial basins with an enormous hydroelectric potential and a large territory account for the configuration of the electricity sector, where hydropower generation[9] is linked to a large transmission network. Transmission lines deliver electricity at high voltage to, for the most part, regional distribution monopolies.

Most of the investments on hydropower facilities were made in the period of 1965 to 1990. These investments were primarily carried out by Eletrobras, a state-owned enterprise which was a holding company comprised of four concessionaries engaged in generation and transmission (Furnas, Chesf, Eletronorte, and Eletronuclear) and two regional distribution utilities (Light and Escelsa).[10] Nevertheless, there occurred a progressive deterioration of the public sector's capacity to invest, caused by the deepening in macroeconomic instability in the 1980's, as well as a widespread inefficiency emerged from a version of rate-of-return regulation. The system utilized a single nationwide uniform tariff accompanied by a compensation scheme to equalize price and cost differentials among firms. The resulting weak sector performance brought about the need of structural reform.[11]

[8] The following is partly based on Goldstein (1999) and Mota (2003).

[9] At the end of 2000, hydroelectric power plants accounted for 88.4% of the total capacity of 67,713 MW.

[10] By the early 1990's, Eletrobras accounted for 57% of total generating capacity, with the remaining 43% being mostly provided by Itaipu, the binational enterprise between Brazil and Paraguai, and vertically integrated utilities owned by the states of Sao Paulo (CESP), Minas Gerais (CEMIG), Parana (COPEL), and Rio Grande do Sul (CEEE).

[11] For details regarding the determinants of structural reform in the electricity sector, see Oliveira and Pires (1994), and Ferreira (2000).

The power sector reforms began in 1995. While constitutional amendments abolished the public monopoly over infrastructure industries and allowed foreign companies to bid for public concessions, the Law 8,987/95 (General Law of Concessions) set the stage for the beginning of the privatization process, represented by the auctions of Escelsa in 1995 and Light in 1996.

In addition, part of the implementation of a new regulatory framework involved the establishment of an independent regulatory agency (ANEEL) in late 1996 and, in the same year, the commission of an international consultancy to study and propose a new model for the electricity sector. The consultant's report was released in 1997 and its proposals were incorporated into Law 9,648, issued on May of 1998.[12] In essence, the approved model focused on privatization and unbundling of generation, transmission and distribution assets, gradual transition to a competitive generation environment in nine years, creation of a wholesale power market, operation of the transmission network by an independent operator, and use of the price-cap regime to regulate distribution tariffs, replacing the previous cost of service system.

Two main points emerge from this reform process. First, the market was opened to private investors while the restructuring was still under study, and before crucial points such as pricing regulation and tariff review procedures were defined. Second, as a consequence of this uncertain context in which it was born, the regulatory agency, in its first years of existence, devoted its resources to refining elements incompletely specified in the law. Staff were engaged in the process of discussing and resolving issues, including developing specifics for the new sector model still to be implemented.[13]

[12] See Ferreira (2000), Mota (2003), and de Oliveira (2003), for detailed descriptions of the new model's characteristics.

[13] The events identified for years 1999 and 2000 are symptomatic of that (Table 2-3).

By the end of 2000, the privatization process had concentrated on distribution companies,[14] reflecting a deliberate intent of privatizing generation only once some key elements of the new model had been established, such as the wholesale power market, and a significant delay in the implementation process itself. Nonetheless, the prospect of an imminent privatization resulted in generation companies controlled by Eletrobras dramatically reducing new investments.

The slow pace of the new model's implementation, the failure in designing an arrangement that could make investments in thermo plants economically viable and a severe drought in the end of 2000 were the main factors behind the Brazilian energy crisis, culminated by the rationing measures announced in May of 2001. The rationing imposed severe losses on both generation and distribution companies, ultimately recognized and authorized to be compensated for by the Government in the so-called *Acordo Geral do Setor* (Sector General Agreement).[15]

The energy crisis also led to a re-evaluation of some of the foundations of the model that had been implemented. In January of 2002, the Government decided to postpone the flotation of the generation companies Furnas, Chesf and Eletronorte, and announced that it would continue establishing the prices of energy supplied by state-owned generators.[16, 17] Then the new Government introduced extensive modifications in sector arrangements, which were officially

[14] A total of 23 companies had been privatized, with 19 being distributors and 4 generators. In 2000, the private sector participation in the distribution and generation markets was 60% and 20%, respectively.

[15] The Agreement established that the losses would be covered by special loans that distribution and generation companies would contract with BNDES, the Brazilian Development Bank. Moreover, it determined that the loans would be paid back with the proceeds from the extraordinary tariff increase (2.9% for residential and rural consumers, and 7.9% for the other consumers).

[16] The Government decided to abolish the disposition (approved by Law 9,648/98) which stipulated that the energy supplied by the state-owned generators would be progressively sold in the free market, at the proportion of one fourth per year, starting in January of 2003. The argument employed was the need to prevent a boom in electricity prices. However, given the negative reaction to its initiative, later on 01/31/02 the Government partly revised its position, defining that the energy would be sold in public auctions, with the minimum price being the one that the state-owned generator had been charging on its contracts.

[17] As a result of these initiatives, the Governments of the States of Sao Paulo and Parana reconsidered the privatization of their electricity companies as well (Cesp and Copel).

announced in July 2003: the formation of a generation pool, discontinuation of the wholesale power market, prohibition of self-dealing, and the commercialization of energy through long term contracts (20 years), to be signed between all generators and distributors. These developments provided the back drop for rate review announcements affecting individual distribution utilities.

Methodology

The event-study technique consists in testing for the existence of significant changes in prices (abnormal returns) of firms' securities at the moment that the event was initially released or announced. The methodology relies on the assumption that stock markets operate efficiently, so that any unanticipated event that has an impact on firm's value will be immediately reflected in security prices, with the price change being an unbiased estimate of the change in firm's future cash flows. As a result of this feature, the methodology has been used to assess the impact of regulatory initiatives in several industries.[18]

In the identification strategy employed in the present study, the standard event-study technique is initially used to check for the existence of abnormal returns at the moment of the regulatory events' announcement. The investigation, at this point, is accomplished by performing both a joint hypothesis test and a constrained regression procedure, where the event's coefficients are forced to be the same across securities, in order to gather evidence on the direction of the event's impacts. The sequence explicitly recognizes that any conclusion regarding a regulatory event's impact has to account for the possibility of event anticipation. Thus, identified cases of significant abnormal returns are checked for the existence of abnormal returns in the 5-day period before the event's announcement. If the anticipation is confirmed, the

[18] Some examples are Rose (1985), Beneish (1991), Prager (1992), Carrol and Landim (1993), and Landim (1999).

event's impact is given by a computed measure of the event's total (or net) abnormal returns. These procedures are detailed below.

Event studies in general usually adopt the statistical method where abnormal returns are modeled as the prediction errors of the regression of security returns on market returns, and hypothesis tests are conducted under the assumption that the residuals are independent and identically distributed (the "market model"). In the context of a regulatory event-study, though, some problems arise. Here, it is quite common to have all or most of the firms in the sample belonging to the same industry, or the regulatory events occurring during the same calendar time period for all firms, violating the independence assumption. Moreover, there is evidence that market model residual variances differ across firms, as a result of the positive relationship between market model residual variance and systematic risk (as well as between the variance of returns and systematic risk).[19]

To account for these potential problems, this study employs the approach developed by Binder (1985b) and Schipper and Thompson (1983), which assumes the following return-generating process for a firm *i*:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \lambda_i DOLLAR_t + \gamma_i LIQUID_t + \sum_{j=1}^{t} \delta_{ij} D_{jt} + \varepsilon_{it}\,, \quad t = 1, \ldots, T \qquad (2\text{-}1)$$

where R_{it} is the return on the security of firm i in period t, R_{mt} is the equally weighted return on the market portfolio in that period (*IBOVESPA*),[20] *DOLLAR* is the percentage variation in the exchange rate in the period t,[21] *LIQUID* stands for a liquidity measure, given by the ratio of

[19] See Fama (1976, pp. 121-124).

[20] Regressions were performed using either the equally weighted (IBOVESPA) or the value-weighted (IBX) indexes of market returns. Better specifications were obtained when the equally weighted index was used.

[21] DOLLAR is given by $((ER_t/ER_{t-1})-1)*100$. The exchange rate expresses the amount of reais needed to buy one dollar, with its increase reflecting an appreciation of the dollar.

negotiated volume at time t to company's market value, D_{jt} is a dummy variable equal to 1 if event j occurred at time t and 0 otherwise, and ϵ_{it} is a random disturbance. Note, for instance, that α_i and β_i are the market model parameters, and δ_{ij} is a measure of the abnormal return associated with event j for firm i.[22]

The *DOLLAR*'s incorporation in the model was motivated by the belief that the oscillation of the exchange rate might have caused differential impacts on companies in the electricity sector. In the period investigated, electricity firms were more exposed to exchange rate fluctuations than the average firm in stock market, since most of them either bought energy from Itaipu (whose tariff is quoted in dollars) or were more indebted in foreign currency than firms from other sectors. Given that changes in the exchange rate and stock market returns are negatively correlated, a negative sign is predicted for *DOLLAR.* The expectation is that an increase in the exchange rate produces a higher (negative) impact on electricity companies,[23] compared to the impact on the average firm in the market (represented by the stock market index).

The *LIQUID*'s inclusion, on its turn, is due to the existing evidence that liquidity helps explain time-series variations in stock returns.[24] In case, the prediction is that *LIQUID* has a positive sign, since it is anticipated that an increase in liquidity over time leads to an increase in

[22] It was tested an alternative specification, where abnormal returns were measured as CAPM prediction errors. In case, the risk-free asset return (given by the SELIC daily variation) was subtracted from both R_{it} and R_{mt}. However, lower R^2 was observed for all individual regressions performed.

[23] Except for the cases of Eletrobrás (which holds a participation of 50% in the Itaipu Enterprise), and the transmission company Transp.

[24] Beneish and Whaley (1996), Lynch and Mendenhall (1997), and Elyasiani, Hauser, and Hauterbach (2000) find evidence of permanent excess returns associated to improvements in the stock's liquidity.

stock returns, as a result of adjustments in stock prices to incorporate the corresponding change (reduction) in transaction costs.[25]

An equation of the above form is specified for each firm in the sample, resulting in a system of N equations for N firms, estimated with a seemingly unrelated regressions procedure. Given that the individual return equations are estimated jointly with generalized least squares, the procedure has the advantage that heteroskedasticity across equations and contemporaneous dependence of the disturbances are explicitly incorporated into the hypothesis tests. Moreover, the approach makes it possible to test the joint hypothesis that all dummy variable coefficients (i.e. the abnormal returns of all firms) for a given event equal zero, which has particular relevance in the context of regulatory events, where it is quite common to have differential impacts (including in sign) among firms in the industry.[26]

The analysis is complemented by another set of hypothesis tests, where the system of equations is estimated with the event coefficients being constrained to be the same across equations (securities). The estimates obtained from this procedure are equal to the estimates which would be obtained from a single regression run on a weighted portfolio of the original securities, where the weights are proportional to the inverse of the estimated covariance matrix of residuals used in the joint GLS estimation (Schipper and Thompson, 1985).[27] The constrained regression procedure provides estimates of the regulatory event parameters and, as such, enables

[25] Investors value liquidity, the quick execution of their orders at the lowest cost. Liquidity, therefore, represents the ease of buying or selling the stock, which can be measured by the bid-ask spread. The more illiquid is the stock, the higher is the spread, or the transaction costs to the investor, and the lower should be the stock's price, which adjusts to incorporate the higher transaction costs. This return-spread relation is taken as a rational response by an efficient market to the existence of the spread (trading friction and transaction costs), rather than an indication of market inefficiency (Amihud and Mendelson, 1986).

[26] When the abnormal returns differ in sign across firms this will frequently be a more powerful test of the hypothesis that the event affects security holder wealth than the test that the average abnormal return equals zero (Binder, 1998).

[27] The estimates represent variance-minimizing weighted averages in which greater weights are given to observations with low variance and low or negative covariance with the other observations (Salinger, 1992).

to get evidence on the direction of the events' impacts and to draw inference in terms of economic significance.

In addition, the sample is composed of companies that operate in the generation, transmission, and distribution sectors, but some of the events are essentially "distribution events," in the sense that they are expected to have an impact on distribution companies only. Since the incorporation of generation and transmission companies' abnormal returns in these cases might end up obscuring the event's effects on distribution firms, hypothesis tests were performed considering two groups of firms, one consisting of all companies in the sample, and another consisting only of the distribution companies.

Hence, the investigation on the existence of abnormal returns at the moment of the events' announcement is carried out by testing the following hypotheses:

H_1: The regulatory event parameters for each firm in the sample are all equal zero;

H_2: The regulatory event parameters for each **distribution** firm in the sample are all equal zero;

H_3: Under the assumption that the event parameters are the same for each firm in the sample, the abnormal return during the event window equals zero;

H_4: Under the assumption that the event parameters are the same for each **distribution** firm in the sample, the abnormal return during the event window equals zero.

For the specific events where the null hypotheses H_1 or H_2 are rejected, the possibility of event anticipation is checked. The same joint hypothesis and constrained estimation tests are applied to the cumulative abnormal returns (CAR) earned by each security in the period of five trading days before the events' announcement.[28] If there is evidence of event anticipation, a

[28]The test for cumulative abnormal returns followed the procedure suggested by Salinger (1992, p.42), which consists in the inclusion of "dummies" for each day t of the event-window as explanatory variables. In the

conclusion regarding the event impact on security returns is taken on the basis of the "event overall effect", given by the results of a new set of hypothesis tests where the event period includes the announcement and the (five) pre-announcement days.

Both stock returns and stock market returns are measured on a daily basis. Consequently, the base specification employs a 1-day event window, which means that it is being tested whether or not the regulatory event had an impact on firms' value in the day it was initially released or announced.[29] Nonetheless, in order to account for the possibility of information leakage in the day before, as well as for the chance that an announcement was made after the closing of the stock market, the study also makes use of 2-day and 3-day event windows.[30]

Due to the missing observation problem (detailed in Section 4 below), the present study investigates the significance of regulatory events of each year, from 1999 to 2003, using the observations from the year under examination and the previous year. This procedure prevented a further reduction in sample size, by enabling the inclusion of stock returns from firms that have a missing observation problem in some years, but not in others.

Data

The sample was limited by availability of data and by the fact that only 34 electricity companies had stocks traded at the Sao Paulo Stock Exchange—BOVESPA, the main Stock Exchange in Brazil.

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observation for period t (t>1), the "dummy" for period t takes on the value 1 and the "dummy" for period t-1 takes on the value –1.

[29] Brown and Warner (1985) provide evidence that shorter event windows increase the power of the tests.

[30] In the 2-day window, the event dummy was set equal to 1 in the event day and in the day immediately after, while in the 3-day case the same was done for the three-day window centered on the event day. On the few occasions where events were close together, the dummies were truncated to prevent overlap.

The information obtained from BOVESPA included daily stock price data related to 31 companies,[31] for the period of 03/16/1998 to 09/30/2003. The data, however, presented a severe missing observation problem. Seventeen companies had more than 40% of observations missing,[32] and were consequently dropped from the sample. Daily stock returns were computed for the remaining 14 firms, resulting in a total of 1372 observations for a company with no missing data.

The computation of stock returns incorporated the necessary adjustments for share splits and rights issues occurred, stock dividends given, and all forms of cash payments made to stockholders.[33] Nonetheless, the transformation of share prices into stock returns increased the number of missing observations. The final sample was then defined considering the number of missing returns in the period of two years of data ($year_t$ and $year_{t-1}$) employed to run the individual regressions for years 1999 to 2003 (Appendix A). Ultimately, stock returns from a total of 12 companies in the electricity sector were used to perform the statistical tests, with the exact number of companies' stock returns employed in each year varying from 9 to 11.

Detailed information regarding these 12 companies is provided in Appendix A. Importantly, the numbers for participation in the distribution and generation markets indicate that the sample is composed of some of the large companies in the electricity sector.[34] These numbers also show that, except for a few cases, it is not possible to come up with a pure classification of the sample companies in terms of belonging to distribution or generation sectors. The

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[31] The data received from BOVESPA did not include daily stock price of firms CPFL Piratininga, Energipe and VBC Energia.

[32] From the mentioned 17 firms, 09 had more than 80% of missing data and 15 were in the above 60% range.

[33] In order to ascertain the correctness of the adjustments performed, the computed daily returns were aggregated into monthly returns and compared to the information on monthly stock performance provided by BOVESPA.

[34] As of December/2000, Eletropaulo, Cemig, Light, Copel, and Celesc were among the eight biggest distribution companies in the country. On the other hand, Eletrobras, Cemig, Cesp, Tractebel, and Copel were, in this order, the five biggest generation companies (Setor Elétrico – Ranking 2001, Vol. 1 – BNDES).

classification reported on the third column, which will be utilized throughout the paper, comes from the comparative analysis of the data regarding electricity delivered to final customers and electricity generated.

The sample implications to the present study are twofold. First, the paper assesses the regulatory events' impact on the large players, which implies that the results cannot be taken to draw conclusions with respect to effects in the electricity sector as a whole. Second, given the existing evidence of an inverse relationship between firm size and systematic risk, as well as the already mentioned relation between systematic risk and variance of returns, the use of larger companies should strengthen the power of the statistical tests.

The identification of the regulatory events was made through the careful analysis of the following material: (a) resolutions, resolution proposals submitted to public hearings, and press releases issued by ANEEL during the period of March 1999 to September 2003; (b) reports in Gazeta Mercantil, the main financial newspaper in Brazil, related to economic regulation of the electricity sector, released in the period of March 1999 to June 2002; and (c) daily reports in the electronic newsletter IFE, jointly provided by Eletrobras and the Economics Institute of the Federal University of Rio de Janeiro (UFRJ), over the period of November 2000 to September 2003.[35] The 65 events listed in Table 2-1 were selected on the basis of their relevance in terms of the new regulatory framework that was being implemented, the expected magnitude of the impact to the stakeholders involved and the repercussion in the media. Note that the events' selection has the date 03/16/1999 as its starting point, given the decision to use at least one year of observations (250 trading days) as the estimation period.

[35] The electronic newsletter IFE collects reports related to electricity regulation released in the following newspapers/magazines: Correio Braziliense, Diário Catarinense, Diário do Grande ABC, Diário do Nordeste, Folha de Pernambuco, Folha de São Paulo, Gazeta Mercantil, InvestNews/GM, Jornal do Brasil, Jornal do Commercio, O Estado do Paraná, O Estado de São Paulo, O Globo, Zero Hora, Valor, and Canal Energia.

The descriptive statistics provided in Table 2-2 depicts a higher variability of stock returns in 1998 and 1999, compared to the other years under examination. Both the range and the computed standard deviation of stock market and securities' daily returns decrease sharply from 1998 to 2003. The higher volatility in stock returns in the first two years examined should make it more difficult to reject the null hypotheses associated with the 1999's events. Note also that the exchange rate varies more in years 1999 and 2002, implying an expected higher impact of this variable on security returns in these years.

The mean liquidity measures indicate that some securities (Fcata, Tract, and Cerj) are not actively traded. Here, the main concern resides in the fact that stocks with irregular transactions may not have incorporated in their prices the change in firms' value brought by an unanticipated event. The correlation matrix (Table 2-3) indicates that this seems to occur with respect to macroeconomic events that affect the market as a whole, since the returns from the less traded securities are the ones which have the smallest correlation with stock market returns. Table 2-3 also reveals, as expected, a significant direct association between volume negotiated and stock market returns (with the logical exception of the least traded stocks)[36] and a negative and significant correlation between market returns and variations in the exchange rate.[37] Notice that some of the sample firms' stock returns display a quite high negative correlation with the exchange rate, which corroborates the need to include this variable in the model specification.

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[36] For some of the not actively traded securities, there is at least an indication that they were more negotiated in days of announcements specific to these firms (their liquidity measure is significantly correlated with their own returns, but not with the market returns). This, however, does not occur with Fcata (the least traded stock), which is also the only security whose daily returns are not significantly correlated with the variation in the exchange rate. Thus, the fact of not being regularly negotiated can be taken as the main reason for the bad specification of Fcata individual regressions, mentioned in Section 5 below.

[37] Due to the evidenced correlation between these variables, we have also performed statistical tests with the *DOLLAR* variable being defined by the residuals of the regression of exchange rate variation on stock market returns. Practically no changes were observed in relation to the event parameter estimates shown in the present study.

The annual exchange rate variation and the annual performance of each stock are displayed in Table 2-4. The exchange rate depreciated highly in years 1999 and 2002, which is in line with the picture shown by Table 2-2. On the other hand, the comparison among sample firms' average stock returns and market index returns reveals that the stocks from the electricity companies included in the sample outperformed the market in the period examined,[38] in spite of the rather poorer performance in year 1999. The present study investigates to what extent the difference in performance can be explained by regulatory decisions.

Findings

The regressions incorporated the necessary adjustments for correlation in security returns over time. The individual regressions' estimated parameters are presented in Table 2-5.[39] The findings indicate that the model is well specified (R^2 in the range of .30 to .80), with a few exceptions in the cases of the three least traded securities already mentioned.[40] As expected, the *IBOVESPA*'s coefficients are positive and strongly significant. The average betas estimated for each firm are in line with the sector of activity examined,[41] whereas the sample average beta shows a U-shaped evolution in the period. The decrease in firms' systematic risk from 1998 to 2000 reflects the reduction in uncertainty brought by the progressive definition of some crucial points of the model being implemented. On the other hand, the beta's increase after 2001 might

[38] The same holds when the Electricity Sector Index (IEE) reported by BOVESPA is compared to the market index. As expected, the sample firms' average stock return and the IEE were highly correlated ($\rho = 0.6956$).

[39] For reasons of space, we do not show the event dummies' estimated coefficients of each individual regression.

[40] The main concern was with respect to Fcata, included in the sample of years 2001 to 2003, whose regressions showed an R^2 in the range of .06 to .11. The results obtained when this security was excluded from the sample were similar to the ones reported in this paper, though. The three cases in which the hypothesis tests provided stronger results are mentioned later on in the text.

[41] For some firms, the low negotiated volume might have resulted in an underestimation of their beta values.

be indicating that the model revision carried out after the energy crisis amplified the regulatory risk.[42]

The *DOLLAR* coefficient is negative and significant in about half of the individual stock returns' regressions, denoting that variations in the exchange rate did provoke a differentiated impact on some firms in the electricity sector, compared to other firms in the stock market. The impact occurs in practically all years examined, and is not more pronounced in years 1999 and 2002, as it was expected. Additionally, the results indicate that liquidity contributes to explaining variations in firms' stock returns, and support the prediction regarding the variable's sign, since the majority of the *LIQUID*'s estimated coefficients is positive and significant. Here, however, as it is possible to anticipate an increase in trading activities in days of important announcements, it should be noted that, in case of events that impact firm's value positively, the *LIQUID*'s estimated coefficient might be capturing part of the estimated announcement effect, leading to an over rejection of the null and to an under estimation of the abnormal returns associated to these events.[43]

Tables 2-6 to 2-10 report the results from the hypotheses tests performed on the sixty-five regulatory events. Before proceeding to their analysis, though, the peculiarity of the regulatory process must be emphasized. In a regulatory context, where the main issues follow the ritual "initial proposal – public hearing – final decision," the events' information content is often leaked or flagged before the regulator's final decision, with the corresponding impact on firms' value being progressively incorporated into stock prices before the official announcement is

[42] It is beyond the scope of this paper the exam of the regulatory events' impact on firms' systematic risk. For studies that address the issue, see Antoniou and Pescetto (1997), Buckland and Fraser (2001), and Morana and Sawkins (2002).

[43] This problem is possibly reduced by the fact that the statistically significant LIQUID's coefficients were, in their majority, the ones related to larger (and with higher trading volume) firms, given that Chordia, Shivakumar, and Subrahmanyam (2004) have found that these firms' liquidity are the least affected by information shocks.

made. As a result, a finding of no significant effect may occur for events that impacted firms' value. It follows that it is harder to reject the null hypotheses H_1 and H_2,[44] when the decision is taken after the implementation of the mentioned process.[45] On the other hand, the occurrence (or not) of significant abnormal returns on rulings set forth after the ritual constitutes evidence regarding the level of consistency and predictability of regulatory decisions.

The peculiarities of the regulatory process, associated to the high volatility that characterized the Brazilian stock market in years 1998 and 1999, may explain the non-rejection of the null hypotheses in any of the 1999's events. In contrast, in years 2000 to 2003 there is evidence of significant abnormal returns for a total of 23 regulatory announcements. Here, the surprise verified in more than one third of the investigated events might be attributed to two main factors: a) the ruling deviated from what the market had anticipated; or b) there were still too much uncertainty regarding the final decision, due to a possibly wide spectrum in terms of regulatory choices and methodologies or simply to the fact that no (or very little) information was provided to the market previously, particularly in cases of rulings not submitted to the mentioned regulatory process. We will return to these points later.

For all of these 23 events, the analysis that follows focused on the outcomes of the tests of hypothesis H_2 and H_4 in case of a "distribution event" and incorporated the results from the

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[44] It also contributed to tougher joint hypothesis tests the incorporation of the *LIQUID* variable in the model, due to the already mentioned expected higher traded volume in days of important announcements, and the fact that most of the firms in the sample were included in the portfolio employed to compute the market index. Consequently, the IBOVESPA captured part of the variation in the sample firms' daily stock prices caused by events specific to the electricity sector (as of December/2001, electricity companies accounted for 12% of the market index, in terms of market capitalization value).

[45] The ritual initial proposal – public hearing – final decision is a practice adopted by the regulatory agency. Therefore, all rulings in which the decision took place at the Government (Ministerial) level did not follow this process. The rulings of this nature amount to 23 out of the 65 events listed in Table 2-1. In addition, some of the regulatory agency's announcements did not follow this process either, mainly because they were just the initial proposal regarding the issue. The ritual occurred in 22 of the (42) ANEEL's announcements listed in Table 2-1. The decisions which do not follow the ritual should convey more information to the market at the moment of their announcement. It is thus expected that they lead to a higher proportion of stock price reactions than the decisions that follow.

constrained regression procedure (columns H_3 and H_4 in Tables 2-6 to 2-10), the cumulative abnormal returns' hypothesis tests (Table 2-11), and the "event overall effect" (Table 2-12), when applicable. Moreover, the examination of the results took into account the findings in terms of each security's abnormal returns at each of the 23 significant events, especially when the evidence indicated the occurrence of differential impact among the sample securities. The same findings, on the other hand, were employed to examine the possibility of the results being driven by a factor other than the regulatory announcement under investigation.[46] In particular, the analysis revealed that in two opportunities (*E012700* and *E010901*) the event's abnormal returns cannot be attributed to the regulatory announcements made on those days, but to some specific factors that affected Light and Fcata, respectively.[47]

It is worth noting that the evidence confirmed the importance of checking for event anticipation, given the finding of significant abnormal returns in the 5-day period before the announcement of 7 out of the 23 significant events (Table 2-11). The need to perform this additional analysis is also illustrated by the results found for *E021700* and *E040803*, which denote that the abnormal returns evidenced in the announcement day are actually an adjustment in market expectations, since the total effect is not significantly different from zero.[48]

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[46] The focus on the results from the tests of hypothesis H_2 and H_4 in case of a distribution event is already a way to control for that. Note, for instance, the results for the distribution event E080503. The rejection of H_1 only (in the 3-day window specification) indicates the occurrence of significant abnormal returns on generation companies' securities, and consequently cannot be credited to the regulatory announcement under exam.

[47] In the case of E012700, the null hypotheses H_1 and H_2 are not rejected when Light is dropped from the sample ($\chi^2 = 6.00$ (p=. 539), and $\chi^2 = 5.14$ (p=. 274), respectively). Moreover, the event's coefficient on Light's individual regression is highly positive, in contrast with the event's expected effect. The same non-rejection of the null hypotheses H_1 and H_2 occurs in E010901 when Fcata is excluded from the sample ($\chi^2 = 9.32$ (p=. 502), and $\chi^2 = 5.85$ (p=. 322), respectively).

[48] Take, for example, the announcement of the "Emergency Plan for the Short-Run" (E040803). In case, while the positive CAR indicates an early incorporation into stock prices of the adopted measures (early on March 31st some newspapers had disclosed the information that the Government would provide resources to help capitalize firms in the sector), the negative abnormal returns on the announcement day reflects the market's surprise with the decision to postpone the incorporation of increases in non-controllable costs (higher price of energy bought from Itaipu, caused by the dollar appreciation) into tariffs, taken to alleviate the impact of tariff adjustments on inflation. In sum,

Information regarding the remaining 19 significant announcements is summarized in Table 2-13. The majority of the significant events caused a positive—as opposed to negative—effect on firms' value, which is in line with the already mentioned better performance of the sample firms' securities over the period, compared to the market portfolio. On the other hand, the results show that a higher proportion of decisions taken at the Ministerial level turn out significant, when contrasted to regulatory agency's decisions, confirming the prediction that Government announcements should convey more information to the market.[49]

As previously stated, finding abnormal returns at Government announcements should be credited more to uncertainty regarding the final decision, than to deviation in market expectations. The distinction is relevant because in the last case the event's estimated impact cannot be taken as a direct measure of the decision effect on firms' value, since the market prior is unknown.[50] In this context, it is interesting to note that the estimated impacts on security returns portrayed in Table 2-13 are, as a general rule, related to the nature of the Government announcements. While a negative impact is evidenced at the disclosure of the rationing plan measures (*E051801*)[51], reflecting their deleterious consequences on companies' future cash flows, positive effects are found for the subsequent compensatory measures undertaken by the

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the non-rejection of the null hypothesis of no "event overall effect" suggests that the unforeseen tariff decision led to a reevaluation of market's previous expectations that firms would be benefited by the Government measures.

[49] 43% (10/23) of Government's rulings turn out significant, against 21% (9/42) of ANEEL's rulings. As anticipated, the difference might be attributed to the fact that Ministerial decisions are less susceptible to information leakage or anticipation, since they do not follow the regulatory process. This result, however, may also reflect the difference in the nature of the decisions taken at the Ministerial and the regulatory agency levels. Since Ministerial rulings focus on the broad definition of the model for the sector, it is expected that they have a higher impact in firms' value than agency's rulings, which in some cases only detail what has been previously defined by the Ministry.

[50] This point is detailed later on in the text.

[51] For both E051801 and E080701, the results are stronger when Fcata is excluded from the sample (χ^2=18.61 (p=.046), and χ^2=10.85 (p= .054), respectively).

Government (*E090601, E102501, E090803*[52], *E091603*). Additionally, the finding of differential impact across firms is consistent with the decision to control the price of energy supplied by state-owned generation companies (*E010902*), a typical within sector redistribution policy, whereas the positive abnormal returns found for *E013102* are in line with the Government's reconsideration of its previous position, materialized by the determination that the state-provided energy would be sold in public auctions.[53]

The negative reaction to the Government's proposed revision in the regulatory agencies' job (*E092303*)[54] is according to expectations as well, since the initiative to limit the agencies' independence constitutes a step back in the electricity sector regulation and induces the fear of a political use of the regulator, increasing the regulatory risk. Note, however, that in two occasions this alignment between the nature of the Government announcement and the estimated effect on security returns is not observed. First, negative abnormal returns are evidenced in case of a compensatory measure (*E081602*),[55] reflecting the decision's implications for Eletrobras and indicating that the market was expecting a better compensation system for the distribution companies. Second, differential impact across firms in the sample is shown for a change in ANEEL's board of directors (*E050201)*, as if the new composition would be beneficial to some firms, but not to others, when no abnormal returns were expected for this event. The new directors were indicated by the same Government that had designated the previous ones, what

[52] The settlement between BNDES and AES in 09/08/03 solved a dispute that had lasted for more that one year, and was interpreted as a signal that the Government was concerned with electricity companies' solvency.

[53] The estimates of this announcement's impact on each of the sample's securities indicated that one distribution company (Eletropaulo) was negatively affected by the Government decision.

[54] See footnote 6.

[55] The Government decided that resources from the 'Reserva Global de Reversao' would be used to cover the reduction in concessionaries' revenues brought by the new criteria for low-income customer (see footnote 57). The negative impact on Eletrobras' security should come from the fact that the mentioned resources were being used by this company to capitalize the seven highly indebted former state-owned distribution companies that were transferred to the Federal Government.

should not signal a change in the way the regulator would rule on regulatory issues in the future. Here, though, the result is not conclusive. The individual securities' coefficient estimates are not consistent by firm type and the CAR's findings suggest the possible early incorporation of the rationing plan measures.

Among the nine regulatory agency's initiatives displayed in Table 2-13, some consist of decisions taken after the implementation of the discussion process previously mentioned. In these cases, the observed effect on security returns denotes that the final decision deviated from market expectations formed along the discussion process, what poses difficulties to an interpretation of the estimated effects on firms' value in the absence of information regarding the market prior.[56] The result found for the ruling defining the basic transmission network (*E111000*), for example, should be revealing that the action taken towards the effective implementation of the model for the electricity sector reduced regulatory uncertainty, but it cannot be ignored the possibility that the positive impact is just a review of (negative) expectations formed on the basis of all the information released or flagged along the regulatory procedure.

One possibility to overcome the problem is to consider the observed reaction to the agency's proposal concerning the issue as a proxy for the market prior.[57] ANEEL's initial proposition on the ruling imposing restrictions on agents' participation in the market (*E041700*) had an impact on stock returns. In case, the estimated event parameter is not significant, indicating the occurrence of differential effects among firms, with some benefiting and others

[56] Regulatory discussion processes usually take two to three months. Thus, eventual abnormal returns occurred along this period, as a result of a progressive incorporation into stock prices of expectations concerning the ruling's impact on firms' value, will not be captured by the CAR check employed in the present study, limited to the 5-day period before the final announcement.

[57] This possibility relies on the assumption that the expectations initially formed on the basis of the regulator's initial proposition do not change in the period that goes up to the announcement of the final decision concerning the issue.

harmed by the proposal. By taking these effects as the market expectations concerning the ruling's impact on firms' value, one may conclude that the positive abnormal returns associated to the final decision (*E072100*) result from adjustments made by the regulator on its original position, making it more aligned with companies' interests.

Similar analysis might be applied to the events related to Escelsa's periodic tariff review. The announcements were embedded with a high signaling power, given the difficulties faced by concessionaries in the rationing period and the fact that it preceded the rate reviews of other companies. Under the generalized uncertainty regarding methodological choices and methods to be used, the positive impact evidenced for the regulator's initial proposal (*E062101*) provides indication of its robustness and soundness. And the finding of another positive impact when the regulator takes its final decision (E080701)[58] denotes that ANEEL made further adjustments in the methodology, interpreted as favoring companies in the sector, or revised upward the repositioning index initially proposed, as if the regulator indeed wanted to signal that was aware of the problems imposed on distribution companies by the rationing plan and would compensate them in the future for that.[59]

Conversely, the results found for the norm issued to define low-income customer (*E050202*) suggest that ANEEL's decision on this topic impacted firms' value negatively.[60] In this case, however, there is no proxy for the market prior, since the previous Congress decision regarding the issue (*E041002*) caused no reaction on stock prices. Nonetheless, the fact that a

[58] See footnote 51.

[59] When asked about compensatory measures to the electricity companies, the President of BNDES affirmed that the Government had been signaling that it would solve the questions pending in the sector, giving as an example the recent tariff increase given to Escelsa (Folha de São Paulo, 10/19/2001).

[60] The prediction was that the new criteria for low-income customer would increase the number of households under this classification from 10.3 million to 18 million, or 36% of the total market (Gazeta Mercantil, May 16th, 2002). The negative impact on firms' returns should come from the fact that low-income customers were exempt from paying the extraordinary tariff increase set forth by the "Sector General Agreement".

negative surprise is found for *E050202* shows that the regulatory agency had some discretion in defining the concept, and used the flexibility to set up a ruling which was not as favorable to firms as the market was expecting.[61]

The findings related to ANEEL's decisions regarding the asset base valuation[62] were unexpected. The voluminous press coverage related to the issue, which invariably reported the distribution companies' disappointment with the proposed reposition cost methodology, led to an expectation of a strong negative impact of ANEEL's initial proposition (*E062102*), not confirmed by the hypothesis tests' results. The findings provide evidence that abnormal returns did occur,[63] but suggest a differential effect across firms, as if the market had been able to realize that the methodology would harm recently privatized companies, by not considering the price paid for the corresponding assets, but benefit the concessionaries that had invested in facilities promoting universal service and built a large asset base.[64] Additionally, the evidence concerning ANEEL's final decision (*E090402*), which kept the same methodology, does not provide support to the alleged surprise that this decision produced on concessionaries.[65] Hence, if the distribution companies expected that the regulator would reconsider its initial proposal, the findings indicate that the market did not. This result, it must be stressed, is consistent with a market belief regarding the regulator's impartiality.

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[61] ANEEL's decision may be interpreted as favoring consumers if it is assumed that the market did not expect a ruling which would favor electricity companies.

[62] Foster and Antmann (2004) provide a detailed overview of the discussion process that resulted in the adoption of the repositioning cost methodology by ANEEL.

[63] The event is significant at the 5% level when Fcata is excluded from the sample (χ^2=11.63, p-value = .040).

[64] Positive coefficient estimates were found for Cemig, Light and Celesc's securities. For Eletropaulo, on the other hand, the results suggest a negative impact.

[65] The Brazilian Electricity Distributors Association (ABRADEE) issued a note, released on 09/04/2002, expressing its surprise with the decision taken by the regulatory agency. According to the Association, there was an ongoing negotiation process with Aneel and other sectors of the Government in order to revise the reposition cost methodology initially proposed (Canal Energia, 09/04/02).

The results related to the announced repositioning indexes, on their turn, provide insights into the level of objectivity and transparency of the methodology employed in the periodic tariff review.[66] Here, the evidence is mixed. The no impact on stock returns found for the repositioning indexes proposed initially (*E021703, E030703, E031103)* denotes that the numbers released were close to market expectations. A significant impact is observed for *E041703*, though, due to the positive abnormal returns caused by the regulatory announcement on Eletropaulo and Light securities.[67] The final indexes announced on this day must have incorporated adjustments made by the regulator, and consequently led to a reevaluation of the expectations concerning these two firms' future tariff reviews. However, the market expectations were not confirmed for Eletropaulo (*E052603*), since its stock prices fell considerably when its own repositioning index was disclosed.[68] This negative surprise suggests the need of improvements in the periodic tariff review methodology, moving to greater predictability.

The results obtained by the present study, when taken together, show that the regulatory decisions which impacted positively electricity firms' value were essentially represented by initiatives taken to effectively implement the model approved by Law 9,648/98 and by measures adopted to compensate firms for the losses imposed by the energy crisis of 2001. These results denote that the need to provide the proper environment and the suitable incentives to the

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[66] The rationale is that, in case of a transparent and objective methodology, the regulator's disclosure of the first repositioning indexes, along with a detailed description of how they were computed, is sufficient for the accurate prediction of the other firms' indexes. The two main points of the methodology employed in the periodic tariff review were the asset base valuation by the repositioning cost and the estimation of 'efficient operational costs' using the reference company approach previously adopted in Spain and Chile.

[67] The estimates for the abnormal returns caused by the announcement on Eletropaulo and Light securities were 5.70 (p=.069) and 8.70 (p=.003), respectively. The event is significant at the 5% level when Fcata is excluded from the sample (χ^2=11.15, p-value = .049).

[68] The estimated abnormal returns caused by *E052603* on Eletropaulo's security was –5.96 (p=. 057).

realization of the so desired investments in electricity generation, transmission and distribution sectors had a high weight in the regulator's utility function[69] over the period examined.

Interestingly, the evidence reveals that most of these "favorable regulatory decisions" were discussed and deliberated at the Ministerial or the Congressional levels, preserving the regulatory agency's impartiality, which is indeed supported by the results. This investigation suggests that ANEEL is seen as a neutral institution and acts as a relatively independent organization. While some of the ANEEL's decisions which significantly affected security returns led to an increase in electricity firms' value, some provoked a differential effect among firms, and some were effectively contrary to companies' interests.

Some caution on this interpretation must be exercised, though, given the fact that every event-study restricts the analysis to decisions which could not be correctly anticipated by the market, a problem that strongly affects regulatory agency's rulings which follow the ritual "initial proposal—public hearing—final decision," compared to Ministerial rulings. On this respect, it must be stressed that finding 5 stock price reactions in 22 cases where the information was flagged or leaked in the regulatory process exceeds what would be expected. Actually, this result constitutes a sign of unpredictability of regulatory agency's decisions.

This finding also provides insights into the applicability to the Brazilian electricity sector regulation of the two opposing theories concerning the pattern of government intervention in business. As a higher predictability should be expected if the regulatory agency consistently serves as an impartial referee that aims to maximize social welfare or consistently favors a specific interest group (Government, industry, or customers), the evidenced unpredictability indicates that the regulatory agency has favored different interest groups at different times,

[69] The word regulator, here, is used in a broad sense. It encompasses not only the regulatory agency, but also other actors with the power to adopt regulatory initiatives, such as the Government (Ministry) and the Congress.

confirming Peltzman's (1976) prediction that the utility maximizing regulator will not exclusively serve a single economic interest.

In terms of economic significance, the results found in the present study indicate that the regulatory decisions examined were responsible for an increase of around 8% in sample firms' market value (Table 2-13). As previously stated, the equally-weighted sample firms' portfolio outperformed the market in the period investigated. A variety of factors might have contributed for these "extra-returns", including efficiency improvements resulting from privatization and implementation of incentive regulation.[70] This research, however, suggests that regulatory decisions account for roughly 12% of the difference in performance of the sample securities with respect to the market index.

Robustness Checks

Two procedures were adopted to examine the robustness of the results found in the present study. First, it was verified the possibility of a small sample bias. In light of the existing evidence that the use of a statistic—such as the chi-squared—whose distribution is only asymptotically known may lead to an over rejection of the null,[71] new hypotheses tests were conducted using Rao's F exact statistic. The findings were practically identical to the ones obtained previously. Consequently, the likelihood of a small sample bias was disregarded.

Secondly, a counterfactual analysis was implemented to check the extent to which the significant abnormal returns evidenced in this study may effectively be attributed to the regulatory announcements investigated or simply result from the Brazilian stock market's volatility. The analysis consisted in the application of the same hypotheses tests to a random set

[70] We are currently addressing the issue in another paper. The results obtained do indicate that privatization and incentive regulation led to efficiency improvements in the Brazilian electricity distribution sector.

[71] Binder (1985a) presents evidence that joint hypothesis tests in the multivariate regression model, using the chi-squared statistics, are biased against the null hypothesis when there are 60, or in some cases even 250 observations, per equation.

of 69 dates.[72] The results displayed in Table 2-14 show the rejection of the null of no abnormal returns in 8 random events. In three of them, however, the same analysis of individual securities' coefficient estimates applied before revealed that the abnormal returns are due to specific factors that affected CERJ (*E090199*) and Eletrobras (*E112601 and E031303*).[73]

Given that one would expect 5% of the random events to be significant, finding significant abnormal returns in 5 of the 69 random events is not out of line. In addition, the result may be due to information leakage, very common in a regulatory context, and thus reflect an early incorporation of regulatory announcements made later on. Nonetheless, it should be emphasized the high disparity between the numbers of significant random events and significant regulatory events, which gives credence to the results provided by this study.

Conclusions

The paper examines the regulator's performance in the Brazilian electricity sector using an event-study methodology specially designed to a regulatory context, which explicitly accounts for the possibility of event anticipation. Despite the more pronounced interests that characterize a developing country's regulatory environment, the results indicate that the regulator has acted relatively independently, with its decisions not favoring a single interest group. The findings are similar to the ones obtained in previous studies that focused in the United Kingdom's context, and do not support the claim that Brazilian regulatory agencies are captured by the industry.

On the contrary, the evidenced unpredictability of regulatory agency's decisions suggests that the regulatory agency has favored different interest groups at different times, supporting the claim that the utility maximizing regulator will not exclusively serve a single economic interest.

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[72] 75 dates were randomly generated in the period of 03/16/1999 to 09/30/2003, but six of them had to be dropped because they were already included in the Events' list.

[73] The test statistics were the following: χ^2=4.03 (p=.854), for *E090199* without Cerj; χ^2=8.66 (p=.565), for *E112601* without Eletrobras; and χ^2=3.76 (p=.927), for E031303 without Eletrobras.

The observed unpredictability, on the other hand, reinforces the need of improvements in the regulatory discussion process, with the adoption of measures to increase the transparency and to promote more substantive public hearings, as recommended by Brown and de Paula (2002, 2004).

The study suggests that the need to provide incentives for new investments has had a significant role in the regulatory process. In addition, electricity companies have been compensated for the regulatory risk they face. The estimates indicate that regulatory decisions led to an increase in firms' market value over the period examined and account for part of the difference of the sample securities' performance with respect to the market.

Some specific findings are also worth noting. The adoption of the asset base repositioning cost methodology was not that harmful to distribution companies, as one would anticipate in light of the press coverage related to the issue, and the evidence raises the concern over the objectivity and transparency of the methodology employed in the distribution companies' periodic tariff review, suggesting the need of improvements. Moreover, the results indicate that the Government's proposal to review the regulatory agencies' responsibilities and performance was seen as a step back in the electricity sector regulation and increased the regulatory risk.

Table 2-1. Events List

Event	*Initiative*	*Description*
E032399	Aneel	Resolution proposal: access to the transmission system
E051099	Aneel	Resolution proposal: definition of the Normative Values
E061099*	Aneel	Extraordinary tariff review
E070199	Aneel	Resolution: regulates the commercialization of energy not previously contracted
E072999	Aneel	Resolution: defines the Normative Values
E080399*	Aneel	Resolution: Escelsa's periodic price review final numbers
E092199*	Aneel	Resolution proposal: quality of service
E092399*	Aneel	Resolution proposal: defines rights and duties of consumers and utilities
E100199	Aneel	Resolution: rules for access to the transmission system
E121499*	Aneel	The regulator denies the requests for an extraordinary tariff review presented by 08 distribution companies
E012700*	Aneel	Resolution: quality of service
E021700	Gov	CELPE's privatization
E041700	Aneel	Resolution proposal: limits for participation in the market (market concentration)
E042400	Aneel	Resolution proposal: rules for the wholesale power market
E050300*	Aneel	Resolution: defines the quality parameter for the X factor in Escelsa's tariff review
E061500	Gov	CEMAR's privatization
E072100	Aneel	Resolution: limits for participation in the market / market concentration
E080400	Aneel	Resolution: rules for the wholesale power market
E111000	Aneel	Resolution: defines the basic transmission network
E112900	Aneel/Gov	Resolution: rights and duties of consumers and utilities / SAELPA's privatization
E120700*	Aneel	Resolution: new quality standards for distribution companies
E010901*	Aneel	Resolution proposal: defines procedures for ordinary, extraordinary and periodic tariff reviews
E042001	Aneel	Intervention in the wholesale power market
E050201	Gov	Change in Aneel's board of directors
E051801	Gov	Announcement of the rationing plan measures
E062101*	Aneel	Regulator's proposal for Escelsa's periodic tariff review
E080701*	Aneel	Resolution: final numbers for Escelsa's periodic tariff review
E090601*	Gov	Compensation for increases in non-controllable costs of distribution companies (MP 2,227/01)
E102501*	Gov	Authorizes that variations in distribution companies' non-controllable costs be adjusted by the Selic interest rate, until the annual tariff review date (Port. 296/01)
E111301*	Gov	Agreement with distribution companies regarding the compensation of rationing losses
E112101*	Aneel	Resolution: details measures implemented by MP 2,227/01 and Port. 296/01
E112301	Gov	Agreement with generation companies regarding the compensation of rationing losses
E121101	Aneel	Decision favoring distribution companies in their dispute against Eletrobras concerning the energy from Itaipu
E121201	Gov	Change in Aneel's board of directors
E121701	Gov	General Sector Agreement
E010902	Gov	Revitalization Plan for the Electricity Sector
E013102	Gov	Announcement that energy supplied by state-owned generators would be sold in public auctions
E020102	Gov	Details of the Revitalization Plan for the Electricity Sector
E021902	Gov	President announces the end of rationing period
E041002	Congress	General Sector Agreement is approved, incorporating a new criterion for low-income consumer.
E042502	Aneel	New criteria makes it more attractive to invest in electricity transmission networks
E050202*	Aneel	Resolution: new criteria for low-income consumer

E060402	Gov	Revitalization Committee announces additional measures of the Revitalization Plan for the Electricity Sector
E062102*	Aneel	Resolution proposal: methodology for asset base valuation
E081602	Gov	Decision to use resources from the RGR to cover revenue reductions brought by low-income consumers' criteria (Decree 4,336/02)
E083002	Aneel	Resolutions: detail Decree 4,336/02 measures; define normative values for contracts with thermo-electric plants; allow distribution companies to contract repairs in the transmission network below 230KV with transmission companies
E090402*	Aneel	Resolution: methodology for asset base valuation
E101502	Aneel	Resolution: credits from pending operations in the wholesale power market must be adjusted for inflation
E103002*	Aneel	Resolution proposal: X-factor methodology
E110702	Aneel	Resolution: reviews the previous definition that credits in the wholesale power market would be adjusted for inflation
E011403*	Aneel	Adoption of the model firm approach in the distributor's periodic tariff review
E021703*	Aneel	Repositioning indexes proposed for the periodic tariff review of Cemig, Cemat, Enersul and CPFL
E030703*	Aneel	Repositioning indexes proposed for RGE and AES SUL
E031103*	Aneel	Repositioning indexes proposed for Coelce, Cosern, Energipe and Coelba
E040803	Gov	Emergency Plan for the Short-Run
E041703*	Aneel	Final repositioning indexes for RGE, AES SUL, Coelce, Cosern, Energipe, Coelba
E043003*	Aneel	Resolution: Electricity Universal Plan
E052603*	Aneel	Repositioning index proposed for Eletropaulo
E070303*	Aneel	Final repositioning index for Eletropaulo
E072103	Gov	General guidelines of the New Model for the Electricity Sector
E080503*	Gov	Emergency Program to help the distribution companies (MP 127/03 – general guidelines)
E090803	Gov	BNDES and AES settle an agreement
E091603*	Gov	Emergency Program to help the distribution companies – announcement of its conditions
E092303	Gov	Law project: revision in regulatory agencies' job
E092503*	Aneel	Repositioning index proposed for Light

Table 2-2. Descriptive Statistics

	1998		1999		2000		2001		2002		2003	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
RetIbov	-0.196	[-15.8, 18.7]	0.421	[-9.9, 33.4]	-0.024	[-6.4, 5.0]	-0.025	[-9.1, 7.6]	-0.053	[-6.5, 6.3]	0.200	[-3.8, 3.6]
	3.960		3.123		2.074		2.140		2.070		1.576	
RetCopel	-0.196	[-15.3, 31.4]	0.382	[-16, 40.9]	0.017	[-6.3, 9.4]	0.092	[-10.3, 9.5]	-0.148	[-8.4, 14]	-0.008	[-9.7, 6.9]
	5.735		4.171		2.858		3.222		3.200		2.970	
RetEletr	-0.492	[-31.9, 29.1]	0.376	[-16.5, 12.1]	-0.003	[-10.9, 11.4]	0.004	[-9.7, 11.4]	-0.310	[-12.1, 21]	0.271	[-8.5, 13.2]
	5.822		3.890		3.168		3.299		4.598		4.046	
RetEletb	-0.293	[-14.1, 25.1]	0.356	[-13.4, 38.5]	-0.005	[-9.6, 19.8]	0.034	[-12.1, 11.6]	-0.024	[-8.8, 11.5]	0.176	[-8.1, 7.7]
	5.767		4.287		2.947		3.466		3.227		3.013	
RetCemig	-0.209	[-24.3, 28.4]	0.335	[-14.6, 30.2]	-0.091	[-7.3, 9.6]	0.111	[-9.0, 8.8]	-0.005	[-10.1, 10]	0.166	[-6.5, 7]
	5.616		4.072		2.764		2.819		3.171		2.305	
RetCesp	-0.177	[-15.6, 17.6]	0.294	[-17, 11.1]	0.362	[-10.3, 25.5]	0.041	[-20.1, 20.3]	-0.236	[-10.1, 12.1]	0.214	[-7.8, 12.7]
	5.062		4.020		4.649		4.738		3.528		3.371	
RetLight	-0.418	[-23.1, 16.7]	0.197	[-18.1, 15.6]	0.099	[-12.5, 14.5]	-0.169	[-18.0, 16.6]	-0.281	[-10.1, 8.7]	0.058	[-11, 15.9]
	4.836		3.845		3.212		3.874		3.193		4.117	
RetCeles	-0.296	[-18.9, 19.5]	0.267	[-14.3, 16.7]	-0.108	[-8.1, 10.2]	-0.033	[-7.6, 20]	0.100	[-7.2, 10.4]	0.070	[-5, 10.4]
	5.212		3.897		3.173		3.524		2.697		2.541	
RetEmae	-0.326	[-31.7, 20.5]	0.739	[-12.6, 34.7]	0.185	[-12.7, 15.9]	0.294	[-10, 20.5]	-0.122	[-11.5, 16.5]	0.032	[-5.8, 13.4]
	8.415		5.859		4.177		3.621		3.251		2.765	
RetFcata	-0.138	[-10, 11.1]	0.307	[-17.2, 20.8]	0.178	[-8.4, 20]	0.097	[-11.5, 22.9]	-0.052	[-12.3, 13.6]	0.105	[-12.1, 9.3]
	2.750		4.639		3.639		3.623		3.426		3.163	
RetCoelc	0.115	[-15.8, 16.8]	0.811	[-11.5, 37.5]	0.201	[-10.4, 9.1]	-0.104	[-7.1, 4.1]	-0.076	[-6.8, 6.5]	0.316	[-5.2, 7.5]
	4.698		4.383		2.639		1.669		2.050		2.060	
RetTranp			0.714	[-15.5, 19.5]	0.201	[-13.4, 35.9]	0.079	[-13.4, 14.4]	0.066	[-10.3, 8]	0.373	[-9.5, 6.6]
			5.720		5.119		3.845		3.105		2.388	
RetCerj	-0.083	[-14.3, 34.6]	0.261	[-33.3, 20]	0.228	[-19.1, 15.2]	0.710	[-14.6, 20]	-0.202	[-13.4, 16]	0.218	[-37, 30.4]
	5.346		5.050		4.210		5.480		4.026		7.144	
RetTract	-0.028	[-18.7, 17.9]	0.117	[-13.9, 21.7]	0.235	[-7.5, 14.4]	0.209	[-7.7, 12.1]	-0.012	[-12, 8.5]	0.455	[-11.6, 23.9]
	4.899		3.405		2.989		4.057		2.849		4.087	
LiqCopel	0.272	[.006, 6.59]	0.233	[.001, 1.80]	0.201	[.009, 1.53]	0.269	[.004, 1.46]	0.370	[.066, 2.31]	0.656	[.053, 3.63]
	0.609		0.213		0.163		0.182		0.256		0.555	
LiqEletr	0.150	[.001, 1.37]	0.193	[.001,1.30]	0.110	[.008, .712]	0.157	[.004, .963]	0.207	[.014, .855]	0.329	[.075, 1.35]
	0.185		0.184		0.096		0.142		0.160		0.198	
LiqEletb	0.476	[.074, 1.77]	0.652	[.001, 2.12]	0.478	[.088, 2.05]	0.515	[.081, 2.48]	0.653	[.124, 3.61]	0.683	[.169, 2.21]
	0.261		0.338		0.265		0.281		0.371		0.323	
LiqCemig	0.462	[.053, 1.65]	0.372	[.001, 2.01]	0.541	[.120, 4.27]	0.459	[.034, 1.65]	0.487	[.083, 1.79]	0.629	[.166, 2.14]
	0.262		0.244		0.472		0.215		0.246		0.306	

LiqCesp	0.591	[.037, 2.43]	0.572	[.002, 2.42]	0.354	[.030, 2.13]	0.335	[.045, 1.57]	0.210	[.017, 1.15]	0.314	[.035, 1.51]
	0.424		0.487		0.289		0.203		0.139		0.279	
LiqLight	0.201	[.008, 3.17]	0.239	[0, 1.74]	0.184	[.008, 3.14]	0.069	[.003, .404]	0.036	[.001, .515]	0.027	[.001, .221]
	0.282		0.228		0.350		0.060		0.051		0.028	
LiqCeles	0.643	[.008, 3.83]	0.893	[.090, 5.28]	0.736	[.078, 5.43]	0.534	[.052, 2.89]	0.612	[.032, 3.16]	0.786	[.071, 6.80]
	0.610		0.703		0.634		0.408		0.509		0.855	
LiqEmae	0.202	[.001, 2.33]	0.162	[.001, 1.83]	0.124	[.001, 1.63]	0.182	[.001, 2.73]	0.049	[.001, .702]	0.104	[.001, .836]
	0.296		0.267		0.216		0.306		0.080		0.120	
LiqFcata	0.058	[.001, 2.81]	0.026	[.001, .227]	0.123	[.001, 4.16]	0.017	[.001, .427]	0.012	[.001, .362]	0.004	[.001, .040]
	0.225		0.039		0.418		0.037		0.035		0.007	
LiqTranp			0.343	[.028, 1.88]	0.386	[.040, 2.90]	0.433	[.063, 17.15]	0.161	[.008, .645]	0.153	[.019, .448]
			0.302		0.405		1.118		0.102		0.091	
LiqCerj	0.041	[.001, .668]	0.113	[.001, 4.57]	0.187	[.001, 3.42]	0.004	[.001, .060]	0.002	[.001, .030]	0.001	[.001, .013]
	0.066		0.303		0.390		0.007		0.005		0.002	
LiqTract	0.123	[.002, .740]	0.080	[.001, 1.65]	0.053	[.001, .542]	0.047	[.001, 2.83]	0.036	[.002, .239]	0.039	[.001, .488]
	0.123		0.143		0.072		0.183		0.036		0.067	
Dolar	0.033	[-.413, .254]	0.174	[-8.44, 11.10]	0.037	[-1.36, 1.81]	0.075	[-3.15, 3.44]	0.181	[-8.93, 4.87]	-0.097	[-2.98, 2.93]
	0.078		1.742		0.511		1.022		1.553		0.967	
Security Returns' Mean Standard Deviation, by Year:												
	5.346		4.403		3.503		3.633		3.255		3.382	

Standard deviations are informed below the mean values.

Table 2-3. Correlation Matrix

	RetIbov	RetCopel	RetEletr	RetEletb	RetCemig	RetCesp	RetLight	RetCeles	RetEmae	RetFcata	RetTranp	RetCerj	RetTract
RetIbov	1.000	0.7484*	0.5621*	0.8192*	0.7755*	0.6090*	0.5143*	0.6006*	0.3797*	0.1480*	0.5363*	0.2697*	0.3987*
		(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
LiqCopel	0.0670*	0.0889*											
	(.013)	(.001)											
LiqEletr	0.1040*		0.1780*										
	(.000)		(.000)										
LiqEletb	0.1117*			0.1552*									
	(.000)			(.000)									
LiqCemig	0.0874*				0.0780*								
	(.001)				(.004)								
LiqCesp	0.0917*					0.1474*							
	(.001)					(.000)							
LiqLight	0.0278						0.0990*						
	(.304)						(.000)						
LiqCeles	0.1009*							0.2016*					
	(.000)							(.000)					
LiqEmae	0.0677*								0.3490*				
	(.013)								(.000)				
LiqFcata	-0.0425									0.0377			
	(.126)									(.233)			
LiqTranp	0.0147										0.1233*		
	(.638)										(.000)		
LiqCerj	0.0861*											0.0937*	
	(.004)											(.003)	
LiqTract	0.0211												0.1737*
	(.444)												(.000)
Dolar	-0.0578*	-0.0910*	-0.1897*	-0.0723*	-0.1190*	-0.1577*	-0.1660*	-0.0876*	-0.1077*	-0.0503	-0.0942*	-0.0827*	-0.0672*
	(.032)	(.001)	(.000)	(.007)	(.000)	(.000)	(.000)	(.001)	(.000)	(.075)	(.002)	(.009)	(.015)

The "*" indicates significance at the 5% level. P-value in parenthesis.

Table 2-4. Securities Returns, Stock Market Returns and Exchange Rate Variation, by Year.

	1998	1999	2000	2001	2002	2003	1998-2003	1999-2003
COPEL	-50.29	109.56	-5.64	10.50	-39.12	-9.30	-40.02	20.66
ELETR	-73.08	108.93	-12.37	-11.69	-64.46	42.73	-77.92	-17.98
ELETB	-58.94	94.09	-11.06	-6.29	-17.22	27.73	-29.77	71.03
CEMIG	-51.16	87.00	-27.40	19.32	-12.83	29.87	-10.43	83.39
CESP	-45.06	-34.68	88.17	-16.20	-52.40	34.45	-63.78	-34.08
LIGHT	-64.85	35.37	12.56	-45.31	-6.57	-4.57	-73.88	-25.70
CELES	-56.85	59.76	-32.50	-20.47	17.39	7.41	-53.34	8.14
EMAE	-71.59	303.85	26.71	75.38	-32.11	-1.01	71.35	503.17
FCATA	-24.23	43.04	31.40	8.41	-24.05	10.64	29.74	71.22
TRANP		81.82	21.26	1.37	4.49	90.46	344.79	344.79
CERJ	-34.23	37.50	30.92	122.13	-22.96	-5.23	92.02	191.95
TRACT	-19.17	16.03	60.77	37.11	-12.28	101.43	265.28	351.92
AVGRET	-48.49	97.08	19.54	20.80	-18.33	32.24	58.32	207.37
IBOVESPA	-41.52	151.93	-10.72	-11.02	-17.01	42.08	38.01	135.99
DOLAR	6.60	48.06	9.30	18.67	52.27	-17.26	157.91	141.94

"AVGRET" displays the returns of the equally-weighted portfolio composed by the securities included in the sample.

Table 2-5. Individual Regressions Results

Year[1]	Variable	RetCopel	RetEletr	RetEletb	RetCemig	RetCesp	RetLight	RetCeles	RetEmae	RetCerj	RetTract	RetFcata	RetTranp	*Avg Beta*[2]
1999	*Ibovespa*	1.024***	0.770***	1.291***	1.087***	0.977***	0.730***	0.828***	0.814***	0.559***				*0.898*
	Dolar	0.070	-0.453***	-0.036	-0.225**	-0.632***	-0.425***	-0.207	-0.521**	-0.454**				
	Liquid	0.124	3.974***	0.601*	-0.471	1.253***	4.184***	0.461*	8.264***	-0.155				
	R-sq	0.6695	0.4730	0.8003	0.7010	0.5246	0.4788	0.4261	0.2985	0.1529				
	N	411	411	411	411	411	411	411	411	411				
2000	*Ibovespa*	0.854***	0.786***	1.096***	0.919***	1.015***	0.659***	0.958***	0.684***		0.489***			*0.829*
	Dolar	0.027	-0.490***	-0.023	-0.200**	-0.566***	-0.437***	-0.175*	-0.547***		-0.042			
	Liquid	1.781***	3.148***	0.805***	0.194	0.853**	2.709***	0.472***	7.745***		8.385***			
	R-sq	0.6127	0.3560	0.6783	0.5524	0.3671	0.3277	0.4553	0.2976		0.3193			
	N	475	475	475	475	475	475	475	475		475			
2001	*Ibovespa*	0.871***	0.750***	1.054***	0.893***	1.102***	0.827***	1.015***	0.699***		0.661***	0.335***	1.156***	*0.903*
	Dolar	-0.200	-0.451***	0.134	0.036	-0.095	-0.156	0.180	-0.419**		0.226	-0.192	0.152	
	Liquid	2.231***	3.307***	0.736*	0.425*	0.177	1.862***	0.402**	4.415***		1.168	0.340	0.386**	
	R-sq	0.4847	0.3416	0.5060	0.5312	0.3604	0.3967	0.4684	0.3133		0.2211	0.1054	0.3392	
	N	468	468	468	468	468	468	468	468		468	468	468	
2002	*Ibovespa*	0.997***	1.026***	1.189***	1.026***	1.164***	0.952***	0.720***			0.804***	0.154**	1.036***	
	Dolar	-0.250***	-0.398***	-0.060	-0.191***	-0.066	0.075	-0.005			0.229**	-0.228**	0.042	*0.990*
	Liquid	1.297***	1.316	0.432	0.237	-0.004	-5.055**	1.379***			0.107	-2.231	-0.037	
	R-sq	0.5635	0.4621	0.6182	0.5654	0.4716	0.4342	0.3749			0.2666	0.0905	0.4705	
	N	487	487	487	487	487	487	487			487	487	487	
2003	*Ibovespa*	1.082***	1.179***	1.265***	1.107***	1.186***	0.887***	0.487***			0.605***	0.134	0.917***	*0.968*
	Dolar	-0.288***	-0.449***	-0.154**	-0.224***	-0.081	0.040	-0.085			0.095	-0.070	-0.011	
	Liquid	0.204	2.848***	0.505*	0.092	2.933***	0.407	1.262***			6.122*	-3.616	1.012	
	R-sq	0.5920	0.4940	0.6733	0.6184	0.5587	0.3604	0.3544			0.1748	0.0611	0.4577	
	N	430	430	430	430	430	430	430			430	430	430	
	Avg Beta	0.966	0.902	1.179	1.006	1.089	0.811	0.802	0.732	0.559	0.640	0.208	1.036	*0.918*

Legend: * p < 0.10; ** p < 0.05; *** p < 0.01

1. For each Year *t*, the regressions include data from periods *t* and *t-1*.
2. The computed annual sample average betas do not incorporate Fcata's measures.

Table 2-6. Hypothesis Tests Results for Events in Year 1999

EVENT	1-DAY WINDOW				2-DAY WINDOW				3-DAY WINDOW			
	H_1	H_2	H_3	H_4	H_1	H_2	H_3	H_4	H_1	H_2	H_3	H_4
	χ^2	χ^2	Coef.	Coef.	χ^2	χ^2	Coef.	Coef.	χ^2	χ^2	Coef.	Coef.
E032399	4.02	1.75	0.22	-0.46	3.80	1.60	-0.30	-0.89	2.81	2.42	-0.83	-0.92
	(.910)	(.941)	(.855)	(.760)	(.923)	(.952)	(.732)	(.384)	(.971)	(.877)	(.237)	(.272)
E051099	9.35	7.82	-1.94	-1.87	4.16	2.13	-1.18	-0.81	5.81	3.51	-0.93	-0.41
	(.405)	(.251)	(.114)	(.213)	(.900)	(.907)	(.176)	(.433)	(.758)	(.742)	(.191)	(.627)
*E061099**	5.89	4.73	1.63	1.47	7.00	4.24	1.88**	1.66	7.28	4.67	1.32*	1.15
	(.750)	(.579)	(.183)	(.326)	(.636)	(.643)	(.030)	(.105)	(.608)	(.587)	(.060)	(.170)
E070199	5.72	4.27	-0.23	0.39	5.22	3.43	-0.31	-0.27	3.67	3.05	-0.30	-0.22
	(.767)	(.640)	(.848)	(.792)	(.815)	(.753)	(.721)	(.790)	(.931)	(.802)	(.667)	(.797)
E072999	4.30	3.68	0.38	0.76	2.98	2.30	0.00	-0.45	6.05	5.11	-0.11	-0.63
	(.890)	(.719)	(.757)	(.614)	(.965)	(.890)	(.999)	(.664)	(.734)	(.529)	(.877)	(.453)
*E080399**	3.07	1.98	-0.72	-0.02	6.09	3.10	-0.39	0.24	3.97	1.89	-0.92	-0.74
	(.961)	(.921)	(.555)	(.989)	(.730)	(.796)	(.655)	(.814)	(.913)	(.929)	(.193)	(.377)
*E092199**	2.08	0.26	-0.75	0.17	3.79	3.31	0.65	1.51	3.49	2.36	0.43	0.96
	(.990)	(.999)	(.539)	(.911)	(.924)	(.768)	(.452)	(.142)	(.941)	(.884)	(.537)	(.252)
*E092399**	8.50	4.09	-0.85	-0.73	5.57	1.84	0.26	-0.37	5.22	1.73	0.27	-0.43
	(.485)	(.663)	(.487)	(.624)	(.782)	(.933)	(.766)	(.721)	(.814)	(.942)	(.756)	(.675)
E100199	2.14	1.60	-0.14	0.27	1.63	0.85	0.10	-0.06	4.71	4.16	0.12	0.00
	(.989)	(.952)	(.908)	(.857)	(.996)	(.990)	(.906)	(.953)	(.859)	(.655)	(.867)	(.999)
*E121499**	3.07	1.84	0.26	0.40	3.14	2.16	-0.60	-0.30	2.99	1.91	-0.67	-0.43
	(.961)	(.933)	(.832)	(.788)	(.958)	(.904)	(.485)	(.768)	(.964)	(.928)	(.344)	(.611)
# Securities	9	9	9	9	9	9	9	9	9	9	9	9
# Observ.	411	411	411	411	411	411	411	411	411	411	411	411

P-value in parenthesis. The “*” denotes a “distribution event”.
Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 2-7. Hypothesis Tests Results for Events in Year 2000

EVENT	1-DAY WINDOW				2-DAY WINDOW				3-DAY WINDOW			
	H_1	H_2	H_3	H_4	H_1	H_2	H_3	H_4	H_1	H_2	H_3	H_4
	χ^2	χ^2	Coef.	Coef.	χ^2	χ^2	Coef.	Coef.	χ^2	χ^2	Coef.	Coef.
*E012700**	23.66***	20.35***	-0.08	1.31	11.87	9.03	-0.76	-0.05	6.46	4.37	-1.09*	-1.13
	(.005)	(.001)	(.938)	(.330)	(.220)	(.107)	(.322)	(.959)	(.693)	(.497)	(.083)	(.130)
E021700	19.39**	7.66	0.58	1.37	18.26**	8.89	0.13	0.91	20.61**	11.57**	0.51	1.49**
	(.022)	(.176)	(.595)	(.309)	(.032)	(.113)	(.862)	(.338)	(.014)	(.041)	(.413)	(.048)
E041700	21.33**	13.90**	-1.26	0.43	13.86	10.30*	-1.27*	-1.08	11.82	9.34*	-1.27**	-1.34*
	(.011)	(.016)	(.246)	(.751)	(.127)	(.067)	(.099)	(.257)	(.223)	(.096)	(.044)	(.075)
E042400	2.54	0.88	0.11	-0.01	3.92	2.65	0.71	0.46	3.86	2.68	0.70	-0.20
	(.979)	(.971)	(.921)	(.991)	(.916)	(.753)	(.355)	(.629)	(.920)	(.748)	(.360)	(.791)
*E050300**	9.49	5.50	0.66	0.28	8.80	4.44	0.59	1.47	8.73	4.46	0.54	0.77
	(.393)	(.358)	(.546)	(.835)	(.456)	(.487)	(.585)	(.121)	(.462)	(.485)	(.618)	(.304)
E061500	13.41	5.74	2.38**	1.61	12.49	7.58	1.87**	1.37	16.51*	5.13	1.25**	0.43
	(.145)	(.332)	(.029)	(.230)	(.187)	(.180)	(.015)	(.147)	(.056)	(.400)	(.046)	(.569)
E072100	25.78***	9.41*	1.98*	0.94	26.77***	9.11	1.61**	1.00	34.26***	12.87**	1.55**	1.07
	(.002)	(.093)	(.069)	(.484)	(.001)	(.104)	(.037)	(.290)	(.000)	(.024)	(.014)	(.155)
E080400	5.90	2.38	-1.77	-1.80	8.11	3.20	-1.54**	-1.03	2.98	0.49	-0.16	-0.06
	(.750)	(.794)	(.104)	(.181)	(.523)	(.669)	(.046)	(.279)	(.965)	(.992)	(.796)	(.936)
E111000	9.22	7.92	0.66	1.20	7.14	4.58	1.15	1.53	16.69*	14.96**	1.21*	1.87**
	(.417)	(.161)	(.545)	(.374)	(.622)	(.469)	(.136)	(.107)	(.053)	(.011)	(.053)	(.012)
E112900	1.04	0.15	0.01	-0.39	1.32	0.61	0.35	0.17	6.03	5.27	1.01	0.98
	(.999)	(.999)	(.994)	(.771)	(.998)	(.987)	(.652)	(.854)	(.736)	(.384)	(.108)	(.190)
*E120700**	6.57	5.33	1.31	1.12	9.40	9.08	-0.35	-0.60	11.75	7.99	-0.40	-0.46
	(.682)	(.376)	(.228)	(.406)	(.401)	(.105)	(.652)	(.531)	(.227)	(.157)	(.520)	(.539)
# Securities	9	9	9	9	9	9	9	9	9	9	9	9
# Observ.	475	475	475	475	475	475	475	475	475	475	475	475

P-value in parenthesis. The "*" denotes a "distribution event".
Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 2-8. Hypothesis Tests Results for Events in Year 2001

EVENT	1-DAY WINDOW				2-DAY WINDOW				3-DAY WINDOW			
	H_1 χ^2	H_2 χ^2	H_3 Coef.	H_4 Coef.	H_1 χ^2	H_2 χ^2	H_3 Coef.	H_4 Coef.	H_1 χ^2	H_2 χ^2	H_3 Coef.	H_4 Coef.
*E010901**	18.19*	13.97**	0.59	0.12	11.05	9.39	0.28	0.10	5.52	4.81	1.13**	1.20*
	(.077)	(.030)	(.565)	(.918)	(.439)	(.152)	(.693)	(.906)	(.903)	(.568)	(.048)	(.071)
E042001	5.59	4.17	-0.22	-0.25	16.51	9.89	-0.99	-0.96	15.64	10.50	-1.17**	-1.16*
	(.899)	(.653)	(.832)	(.837)	(.123)	(.129)	(.163)	(.245)	(.154)	(.105)	(.042)	(.084)
E050201	13.94	9.70	-0.41	0.11	21.53**	10.00	-0.10	0.24	12.12	4.93	-0.19	-0.40
	(.236)	(.137)	(.686)	(.925)	(.028)	(.124)	(.885)	(.775)	(.354)	(.552)	(.740)	(.545)
E051801	16.90	11.52*	-0.94	-1.04	18.63*	10.20	-1.77**	-1.41*	12.78	5.21	-0.86	-0.71
	(.111)	(.073)	(.360)	(.377)	(.068)	(.116)	(.012)	(.086)	(.308)	(.516)	(.133)	(.287)
*E062101**	19.79**	12.92**	2.08**	2.42**	30.05***	9.62	1.59**	1.08	46.36***	12.73**	1.53***	1.03
	(.048)	(.044)	(.044)	(.042)	(.001)	(.141)	(.030)	(.204)	(.000)	(.047)	(.009)	(.128)
*E080701**	5.47	2.81	0.74	1.29	11.76	11.03*	1.33*	2.01**	8.33	6.90	0.70	1.16*
	(.906)	(.832)	(.471)	(.274)	(.381)	(.087)	(.060)	(.014)	(.683)	(.330)	(.222)	(.083)
*E090601**	23.10**	13.77**	0.32	0.72	30.08***	16.20**	0.53	0.56	27.34***	13.71**	1.42**	1.59**
	(.017)	(.032)	(.757)	(.543)	(.001)	(.012)	(.451)	(.499)	(.004)	(.033)	(.014)	(.017)
*E102501**	27.01***	19.62***	-0.20	-0.14	33.58***	28.72***	-0.18	-0.31	25.73***	17.71***	-0.54	-0.52
	(.004)	(.003)	(.846)	(.908)	(.000)	(.000)	(.804)	(.708)	(.007)	(.007)	(.345)	(.436)
*E111301**	5.06	1.92	0.68	0.54	4.72	1.60	0.91	0.55	5.20	2.79	0.33	0.07
	(.928)	(.927)	(.507)	(.647)	(.944)	(.952)	(.196)	(.499)	(.921)	(.834)	(.560)	(.912)
*E112101**	16.16	9.23	1.06	0.84	14.14	9.72	1.28*	1.38*	11.30	8.17	0.72	0.76
	(.135)	(.161)	(0.300)	(.473)	(.225)	(.137)	(.069)	(.093)	(.418)	(.226)	(.208)	(.252)
E112301	4.33	2.45	0.61	0.71	15.67	7.20	0.36	1.15	16.61	7.40	0.38	1.18
	(.959)	(.873)	(.548)	(.545)	(.153)	(.302)	(.610)	(.162)	(.120)	(.285)	(.586)	(.150)
E121101	6.87	3.38	0.46	0.46	7.28	3.43	0.46	0.47	17.73*	4.03	0.80	0.60
	(.809)	(.759)	(.653)	(.695)	(.776)	(.753)	(.646)	(.683)	(.088)	(.673)	(.259)	(.465)
E121201	17.12	8.70	-0.61	-2.03*	16.24	11.69*	-0.68	-1.26	16.13	11.33*	-0.68	-1.26
	(.104)	(.191)	(.552)	(.084)	(.132)	(.069)	(.334)	(.124)	(.136)	(.078)	(.332)	(.124)
E121701	8.99	7.48	0.05	0.45	14.28	8.64	-0.07	0.34	10.98	5.99	-0.12	0.31
	(.623)	(.278)	(.961)	(.700)	(.217)	(.194)	(.924)	(.675)	(.445)	(.424)	(.836)	(.640)
# Securities	11	11	11	11	11	11	11	11	11	11	11	11
# Observ.	468	468	468	468	468	468	468	468	468	468	468	468

P-value in parenthesis. The "*" denotes a "distribution event".
Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 2-9. Hypothesis Tests Results for Events in Year 2002

EVENT	1-DAY WINDOW				2-DAY WINDOW				3-DAY WINDOW			
	H_1 χ^2	H_2 χ^2	H_3 Coef.	H_4 Coef.	H_1 χ^2	H_2 χ^2	H_3 Coef.	H_4 Coef.	H_1 χ^2	H_2 χ^2	H_3 Coef.	H_4 Coef.
E010902	9.29	7.45	0.33	0.96	27.77***	17.00***	-0.92	-0.15	18.66**	11.59*	-0.49	0.12
	(.504)	(.281)	(.744)	(.406)	(.002)	(.009)	(.202)	(.851)	(.045)	(.071)	(.396)	(.852)
E013102	33.22***	19.27***	1.97*	0.97	30.18***	18.22***	2.03**	0.95	28.67***	23.41***	2.14***	1.89**
	(.000)	(.004)	(.056)	(.402)	(.001)	(.006)	(.046)	(.406)	(.001)	(.001)	(.003)	(.019)
E020102	6.53	4.53	0.82	0.82	8.25	6.16	0.73	0.83	8.01	6.07	0.73	0.83
	(.769)	(.604)	(.422)	(.478)	(.604)	(.405)	(.303)	(.302)	(.627)	(.415)	(.298)	(.303)
E021902	5.44	3.06	-0.64	-0.71	10.87	9.40	-0.08	-0.35	12.43	10.64	-0.03	-0.24
	(.859)	(.801)	(.528)	(.537)	(.367)	(.152)	(.915)	(.666)	(.257)	(.100)	(.962)	(.717)
E041002	6.48	6.14	1.65	1.83	6.05	2.95	0.90	0.74	2.37	1.99	0.41	0.39
	(.773)	(.407)	(.107)	(.114)	(.810)	(.815)	(.206)	(.361)	(.992)	(.920)	(.474)	(.549)
E042502	10.95	9.70	1.07	1.66	11.35	10.09	1.05	1.69	9.08	5.54	0.97	1.20
	(.361)	(.138)	(.296)	(.152)	(.331)	(.120)	(.298)	(.140)	(.524)	(.476)	(.169)	(.134)
*E050202**	16.45*	14.14**	-2.05**	-2.34**	7.72	4.63	-1.05	-1.04	6.18	4.75	-0.78	-0.75
	(.087)	(.028)	(.046)	(.043)	(.656)	(.592)	(.141)	(.197)	(.800)	(.576)	(.179)	(.257)
E060402	5.00	2.62	0.59	1.55	2.42	0.89	-0.28	-0.21	1.44	0.85	-0.35	-0.34
	(.891)	(.854)	(.561)	(.178)	(.992)	(.989)	(.690)	(.798)	(.999)	(.990)	(.543)	(.607)
*E062102**	13.43	12.16*	0.78	0.88	5.52	4.15	-0.68	-0.58	7.45	6.52	-0.21	-0.08
	(.200)	(.058)	(.447)	(.451)	(.853)	(.656)	(.340)	(.477)	(.682)	(.367)	(.714)	(.905)
E081602	22.16**	10.38	0.82	1.35	16.67*	7.01	0.63	1.39*	13.35	4.47	0.01	0.77
	(.014)	(.109)	(.426)	(.241)	(.082)	(.319)	(.380)	(.084)	(.204)	(.612)	(.981)	(.243)
E083002	30.91***	21.10***	-1.02	-1.51	10.78	9.06	-0.71	-1.14	4.00	2.20	0.12	0.19
	(.000)	(.002)	(.323)	(.194)	(.374)	(.170)	(.320)	(.157)	(.947)	(.900)	(.841)	(.775)
*E090402**	4.56	3.86	-1.27	-1.52	8.23	6.65	-0.65	-0.90	9.21	6.19	-0.94	-1.12*
	(.918)	(.695)	(.213)	(.188)	(.606)	(.354)	(.359)	(.263)	(.512)	(.402)	(.103)	(.088)
E101502	9.95	7.11	-0.90	-0.95	10.32	8.74	-1.46**	-1.75**	6.34	4.37	-1.20**	-1.30**
	(.444)	(.310)	(.380)	(.408)	(.412)	(.188)	(0.040)	(.030)	(.786)	(.626)	(.038)	(.048)
*E103002**	5.12	3.35	-1.18	-1.42	10.93	8.42	-1.05	-1.23	7.80	6.98	-0.50	-0.43
	(.883)	(.763)	(.252)	(.220)	(.362)	(.208)	(.144)	(.130)	(.648)	(.323)	(.393)	(.516)
E110702	10.37	5.01	-1.65	-1.07	6.46	3.17	-1.03	-0.68	6.44	3.01	-1.04	-0.66
	(.408)	(.542)	(.106)	(.354)	(.775)	(.786)	(.148)	(.396)	(.776)	(.807)	(.142)	(.411)
# Securities	10	10	10	10	10	10	10	10	10	10	10	10
# Observ.	487	487	487	487	487	487	487	487	487	487	487	487

P-value in parenthesis. The “*” denotes a “distribution event”.
Legend: * p < 0.10; ** p < 0.05; *** p < 0.01.

Table 2-10. Hypothesis Tests Results for Events in Year 2003

EVENT	1-DAY WINDOW				2-DAY WINDOW				3-DAY WINDOW			
	H_1	H_2	H_3	H_4	H_1	H_2	H_3	H_4	H_1	H_2	H_3	H_4
	χ^2	χ^2	Coef.	Coef.	χ^2	χ^2	Coef.	Coef.	χ^2	χ^2	Coef.	Coef.
*E011403**	9.93	6.28	-0.04	-0.36	6.63	5.14	-0.23	-0.53	1.39	1.19	-0.19	-0.27
	(.446)	(.392)	(.968)	(.744)	(.760)	(.525)	(.738)	(.515)	(.999)	(.977)	(.726)	(.681)
*E021703**	7.85	6.00	-0.18	-0.05	7.37	3.54	-0.64	-0.39	5.42	2.01	-0.37	-0.37
	(.643)	(.423)	(.851)	(.962)	(.690)	(.738)	(.344)	(.626)	(.861)	(.918)	(.501)	(.576)
*E030703**	11.08	7.21	1.40	2.34**	9.51	4.39	-0.24	0.64	3.90	2.67	0.05	0.49
	(.351)	(.301)	(.141)	(.036)	(.484)	(.623)	(.723)	(.426)	(.951)	(.849)	(.929)	(.458)
*E031103**	9.00	3.97	-0.54	-1.23	11.56	6.64	-0.12	-1.03	10.79	6.09	-0.09	-0.98
	(.532)	(.681)	(.565)	(.271)	(.315)	(.355)	(.854)	(.201)	(.373)	(.413)	(.895)	(.221)
E040803	22.65**	17.46***	-1.81*	-3.54***	46.45***	25.85***	-1.13*	-2.65***	44.90***	24.81***	-1.18*	-2.66***
	(.012)	(.008)	(.059)	(.002)	(.000)	(.000)	(.098)	(.001)	(.000)	(.000)	(.079)	(.001)
*E041703**	14.71	12.27*	0.78	1.09	14.76	3.03	0.00	-0.22	23.74***	6.19	-0.24	-0.62
	(.143)	(.056)	(.413)	(.330)	(.141)	(.804)	(.998)	(.782)	(.008)	(.402)	(.665)	(.341)
*E043003**	18.25*	6.67	1.31	1.61	11.86	8.10	0.32	0.39	10.91	6.64	-0.03	-0.33
	(.051)	(.352)	(.169)	(.151)	(.294)	(.231)	(.635)	(.631)	(.364)	(.355)	(.956)	(.614)
*E052603**	7.73	6.08	-1.40	-2.17*	9.39	8.82	-0.50	-0.58	6.81	6.54	-0.24	-0.54
	(.654)	(.414)	(.140)	(.053)	(.495)	(.183)	(.464)	(.474)	(.743)	(.365)	(.659)	(.413)
*E070303**	8.28	5.80	-0.09	-0.44	13.04	2.71	0.68	-0.03	13.05	1.87	0.98*	0.40
	(.601)	(.445)	(.925)	(.697)	(.221)	(.843)	(.315)	(.974)	(.220)	(.931)	(.073)	(.539)
E072103	2.43	1.37	-0.22	-0.49	4.89	2.20	0.07	-0.10	3.24	1.35	-0.29	-0.35
	(.991)	(.967)	(.815)	(.664)	(.898)	(.900)	(.922)	(.903)	(.975)	(.968)	(.602)	(.597)
*E080503**	7.71	2.88	-0.10	0.81	7.46	3.58	-0.94	-0.68	20.69**	4.08	0.12	-0.44
	(.657)	(.824)	(.919)	(.469)	(.681)	(.732)	(.166)	(.397)	(.023)	(.666)	(.823)	(.497)
E090803	11.92	9.44	0.16	0.64	47.52***	44.84***	0.94	1.97**	39.44***	36.50***	1.08*	2.00***
	(.290)	(.150)	(.866)	(.567)	(.000)	(.000)	(.167)	(.015)	(.000)	(.000)	(.051)	(.003)
*E091603**	20.55**	7.23	1.22	1.56	11.99	4.11	0.57	0.60	18.72**	5.89	0.75	0.43
	(.024)	(.300)	(.199)	(.165)	(.285)	(.661)	(.399)	(.458)	(.044)	(.435)	(.176)	(.511)
E092303	9.90	9.32	-0.33	-0.33	20.44**	18.74***	-0.40	-0.42	14.07	11.58*	-0.62	-0.44
	(.449)	(.156)	(.731)	(.772)	(.025)	(.004)	(.557)	(.600)	(.170)	(.072)	(.258)	(.505)
*E092503**	13.60	7.69	-0.47	-1.73	8.03	3.53	0.07	-0.86	8.13	3.58	0.07	-0.83
	(.192)	(.261)	(.619)	(.123)	(.626)	(.740)	(.922)	(.285)	(.616)	(.733)	(.922)	(.297)
# Securities	10	10	10	10	10	10	10	10	10	10	10	10
# Observ.	430	430	430	430	430	430	430	430	430	430	430	430

P-value in parenthesis. The "*" denotes a "distribution event".
Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 2-11. Hypothesis Tests Results for CARs Before Significant Events

EVENT	H_1 χ^2	H_2 χ^2	H_3 Coef.	H_4 Coef.
E012700	5.29 (.808)	3.84 (.573)	-0.15 (.951)	-0.61 (.830)
E021700	27.03*** (.001)	12.69** (.026)	-1.62 (.499)	-1.57 (.581)
E041700	4.82 (.777)	1.71 (.887)	1.39 (.588)	1.05 (.724)
E072100	3.33 (.950)	1.56 (.906)	-0.42 (.862)	-2.05 (.466)
E111000	6.13 (.727)	5.45 (.364)	3.01 (.207)	3.66 (.195)
E010901	21.69** (.027)	18.44*** (.005)	2.41 (.265)	4.25* (.080)
E050201	15.89 (.145)	10.79* (.095)	-3.54 (.103)	-6.03** (.013)
E051801	12.23 (.346)	7.31 (.293)	-1.12 (.604)	-2.50 (.302)
E062101	2.79 (.993)	2.30 (.889)	1.63 (.452)	1.54 (.524)
E080701	4.67 (.946)	1.74 (.942)	1.24 (.567)	0.94 (.696)
E090601	7.99 (.714)	6.56 (.363)	3.50 (.104)	3.55 (.142)
*E102501**	32.46*** (.001)	26.88*** (.001)	4.95** (.022)	6.05** (.013)
E010902	4.56 (.918)	1.60 (.952)	-0.82 (.709)	-0.36 (.883)
E013102	17.24* (.069)	6.93 (.327)	-0.38 (.863)	-3.24 (.190)
E050202	3.22 (.975)	1.12 (.980)	0.27 (.904)	1.53 (.537)
E062102	7.86 (.642)	7.61 (.268)	4.45** (.044)	5.29** (.034)
E081602	22.71** (.012)	21.55*** (.002)	-6.37*** (.004)	-8.82*** (.000)
E083002	8.62 (.568)	1.86 (.932)	-0.89 (.686)	0.65 (.792)
E040803	33.71*** (.001)	18.53*** (.005)	2.74 (.196)	5.65** (.025)
*E041703**	38.71*** (.000)	4.22 (.647)	2.01 (.322)	0.74 (.757)
E090803	14.88 (.136)	12.51* (.052)	1.81 (.375)	4.43* (.068)
*E091603**	46.22*** (.000)	29.26*** (.001)	5.08*** (.007)	3.59 (.113)
E092303	25.99*** (.004)	18.60*** (.005)	-4.37** (.016)	-3.71* (.086)

P-value in parenthesis. The “*” denotes a “distribution event”.
Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 2-12. Hypothesis Tests' Results for Events' Overall Effect

EVENT	H_1 χ^2	H_2 χ^2	H_3 Coef.	H_4 Coef.
E021700	11.48 (.244)	6.47 (.263)	-0.69 (.797)	2.69 (.399)
*E102501**	29.85*** (.002)	24.19*** (.001)	4.52* (.067)	5.55* (.065)
E081602	17.71* (.060)	16.39** (.012)	-5.60** (.026)	-7.52*** (.008)
E040803	11.98 (.286)	6.82 (.338)	0.48 (.847)	2.14 (.472)
*E091603**	42.16*** (.000)	25.80*** (.000)	6.09*** (.005)	4.54* (.081)
E092303	16.09* (.097)	11.14* (.084)	-5.25** (.012)	-4.94** (.049)

P-value in parenthesis. The “*” denotes a “distribution event”. The event overall effect was computed only for significant events whose hypothesis tests rejected the null that the CARs in the 5-day period before the announcement was not different from zero (in case of *E010901*, the analysis showed that the observed abnormal returns could not be attributed to the announcement examined).
Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 2-13. Significant Announcements' Categorization. Direction and Estimated Magnitude of Regulatory Announcements' Effect on Security Returns

Positive Impact				Negative Impact				Differential Impact Across Firms in the Sample		
Type of Announcement	*Event*	*Initiative*	*Estimated Abnormal Returns*	*Type of Announcement*	*Event*	*Initiative*	*Estimated Abnormal Returns*	*Type of Announcement*	*Event*	*Initiative*
Initiative to implement the model for the electricity sector (final ruling on agents' participation in the market)	*E072100*	Aneel	1.98	*Rationing Plan*	*E051801*	Gov	-1.77	*Initiative to implement the model for the electricity sector (proposed ruling on agents' participation in the market)*	*E041700*	Aneel
Initiative to implement the model for the electricity sector (definition of the basic transmission network)	*E111000*	Aneel	1.21	*Initiative to implement a Congress' decision (definition of low-income customer's concept)*	*E050202*	Aneel	-2.34	*Change in ANEEL's board of directors*	*E050201*	Gov
Rate decision (initial proposal)	*E062101*	Aneel	2.08	*Compensatory measure*	*E081602*	Gov	-5.60	*Within sector redistribution policy*	*E010902*	Gov
Rate decision (final decision)	*E080701*	Aneel	2.01	*Revision in regulatory agencies' job*	*E092303*	Gov	-5.25	*Initiative to implement the model for the electricity sector (proposed ruling on asset base valuation methodology)*	*E062102*	Aneel
Compensatory Measure	*E090601*	Gov	1.42					*Several rulings issued in the same day*	*E083002*	Aneel
Compensatory Measure	*E102501*	Gov	4.52							
Partial revision of a within sector redistribution policy previously adopted	*E013102*	Gov	2.14							
Compensatory Measure	*E090803*	Gov	1.08							
Compensatory Measure	*E091603*	Gov	6.09							
Rate decision (final decision)	*E041703*	Aneel	1.09							

Includes only the events for which the null hypotheses H_1 or H_2 were rejected. Events *E012700*, *E010901*, *E021700*, and *E040803* were dropped, however, because a deeper analysis revealed that either the abnormal returns could not be attributed to the regulatory announcements investigated or the impact observed in the announcement day was actually a review in market expectations concerning the event's effect.

Table 2-14. Random Events' Results

Event	*1999* H₁ χ^2	H₂ χ^2	Event	*2000* H₁ χ^2	H₂ χ^2	Event	*2001* H₁ χ^2	H₂ χ^2	Event	*2002* H₁ χ^2	H₂ χ^2	Event	*2003* H₁ χ^2	H₂ χ^2
E041499	12.87	10.82	*E012400*	8.54	4.96	*E011001*	14.29	8.62	*E012302*	6.40	4.35	*E021003*	9.54	6.19
	(.168)	(.094)		(.481)	(.420)		(.217)	(.196)		(.780)	(.629)		(.481)	(.402)
E042399	16.38*	14.22	*E021000*	13.74	1.69	*E012901*	5.48	3.27	*E030102*	5.95	1.79	*E030503*	8.89	4.21
	(.059)	(.027)		(.132)	(.890)		(.905)	(.774)		(.745)	(.937)		(.542)	(.648)
E051899	10.94	7.71	*E022500*	4.14	3.09	*E021501*	6.11	2.97	*E032702*	1.78	1.00	*E031303*	19.24**	1.70
	(.280)	(.260)		(.902)	(.686)		(.865)	(.812)		(.997)	(.985)		(.037)	(.944)
E060199	4.99	2.95	*E032000*	10.48	8.55	*E042701*	13.71	8.80	*E040102*	18.33**	16.79***	*E032503*	6.76	4.80
	(.835)	(.815)		(.313)	(.128)		(.249)	(.185)		(.049)	(.010)		(.747)	(.569)
E090199	21.03**	20.27***	*E032300*	6.49	5.74	*E070201*	17.14	12.46*	*E042302*	5.32	3.64	*E032703*	6.48	6.16
	(.013)	(.003)		(.690)	(.332)		(.103)	(.052)		(.868)	(.725)		(.773)	(.405)
E092099	3.85	1.44	*E041400*	11.08	2.51	*E070501*	26.33***	20.00***	*E042902*	8.35	4.96	*E052803*	4.08	3.63
	(.921)	(.963)		(.270)	(.775)		(.006)	(.003)		(.594)	(.548)		(.943)	(.727)
E110399	4.49	1.76	*E041900*	5.03	4.36	*E080601*	6.51	3.62	*E050902*	11.92	9.33	*E070403*	13.15	3.62
	(.876)	(.940)		(.754)	(.499)		(.837)	(.728)		(.290)	(.155)		(.215)	(.727)
E110899	3.63	2.99	*E042000*	22.02***	19.26***	*E083101*	9.99	6.24	*E060502*	12.16	6.46			
	(.934)	(.811)		(.005)	(.002)		(.531)	(.397)		(.274)	(.374)			
E120999	7.76	7.51	*E052200*	2.38	1.31	*E100401*	11.57	3.83	*E070202*	3.70	1.03			
	(.559)	(.276)		(.983)	(.933)		(.396)	(.700)		(.960)	(.984)			
E121099	8.57	4.21	*E062600*	5.57	3.74	*E102401*	13.89	5.94	*E072502*	11.32	5.45			
	(.478)	(.649)		(.781)	(.588)		(.238)	(.429)		(.333)	(.487)			
			E072000	13.21	5.32	*E102901*	18.78	8.43	*E080702*	7.40	4.74			
				(.153)	(.377)		(.065)	(.208)		(.686)	(.577)			
			E090600	5.55	1.03	*E103001*	8.05	7.09	*E080802*	27.70***	19.81***			
				(.784)	(.959)		(.708)	(.312)		(.002)	(.003)			
			E091300	3.09	2.58	*E112201*	6.03	5.14	*E093002*	19.67**	15.18**			
				(.960)	(.764)		(.871)	(.525)		(.032)	(.019)			
			E092100	4.89	4.47	*E112601*	21.79**	6.32	*E101102*	2.84	1.57			
				(.844)	(.484)		(.026)	(.388)		(.984)	(.954)			
			E101000	4.38	1.08	*E113001*	18.4*	5.54	*E101802*	11.29	4.42			
				(.884)	(.955)		(.072)	(.476)		(.335)	(.619)			
			E102300	5.61	4.84				*E102202*	13.65	11.33*			
				(.778)	(.435)					(.189)	(.078)			
			E103100	5.28	3.55				*E111102*	4.50	3.96			
				(.809)	(.615)					(.875)	(.682)			
			E111600	6.86	4.91				*E111402*	5.61	1.86			
				(.651)	(.427)					(.847)	(.931)			
			E120100	10.14	6.49									
				(.339)	(.261)									

P-value in parenthesis. Legend: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

CHAPTER 3
PRIVATIZATION, INCENTIVE REGULATION, AND EFFICIENCY IMPROVEMENTS IN THE BRAZILIAN ELECTRICITY DISTRIBUTION INDUSTRY

Introduction

Network industries have experienced a remarkable change in the last twenty years. Once characterized by state-owned, vertically-integrated companies, electricity power, telecommunications, natural gas, water & sewerage, railroads, and ports industries from several countries have gone through a reform process which encompasses unbundling, privatization, introduction of market-oriented regimes for their competitive segments, and implementation of a new regulatory framework for the remaining segments with natural monopoly characteristics.

The new regulatory framework has involved the creation of independent regulatory bodies and the incorporation of theoretical advances from the economics literature on incentive regulation. Here, the regulator is seen as a social welfare maximizer operating in a context of imperfect and asymmetric information regarding firms' demand, cost opportunities, and managerial effort. The regulator seeks to limit the regulated firms' rents and to allocate some of these rents to consumers, subject to a firm break-even constraint.[1] In this context, some incentive mechanisms emerge as an alternative to the customarily employed cost-of-service or rate of return regulation. Under a price-cap regime[2], the most popular regulation, prices are fixed. The firm and its managers are the residual claimants on production cost reductions, and bear the

[1] For a comprehensive review of the theoretical literature on incentive regulation, see Laffont and Tirole (1993), and Armstrong and Sappington (2003).

[2] Sappington (2002) provides details on the design and implementation of price-cap regulation, as well as of other forms of incentive regulation.

disutility of increased managerial effort (Joskow, 2005). Thus, the conditions and incentives for efficiency improvement[3] and for the possible achievement of second best prices are settled.

Whether price-cap regulation effectively leads to efficiency improvements, however, constitutes an empirical question, given the different ways in which it is implemented in practice.[4] Benchmarking, or comparative efficiency analysis, is a technique used to address the issue of relative performance since it enables the computation of efficiency scores and the analysis of their evolution over time. More than that, by providing information on each firm's inherent cost opportunities, the benchmark exercise helps alleviate the potential adverse selection problem faced by the regulator, consequently allowing the establishment of cost-effective prices at the scheduled tariff review. From the researchers' perspective, though, it allows an ex-post evaluation of the new prices the regulator has set.

The present study uses a benchmarking methodology to assess the impact of privatization and incentive regulation on firms' performance. The related literature on the electricity distribution sector is limited, possibly due to a reduced number of observations and data availability constraints.[5] Nonetheless, for the empirical studies that have addressed the topic, the general finding is that privatization has been associated with improvements in efficiency,

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[3] The theory states that price-cap regulation provides incentives to improvements in performance in other dimensions as well, such as innovation, efficient choice of operating technology, and even service quality. In this paper, however, I focus on the efficiency improvement possible impact only.

[4] The length of time between schedule reviews and the degree of association of prices to realized costs, for example, may mitigate the efficiency improvements incentives brought by price-cap regulation. When a price-cap plan links future prices directly to realized costs and the time between schedule reviews is relatively short, the incentives under a price-cap regime are similar to the ones under rate of return regulation (Sappington, 2002).

[5] Given the natural monopoly characteristic of electricity distribution, there is a small number of firms in most countries which have undertaken sector reforms. In addition, there does not exist, up to this moment, a widespread understanding among regulators of the need to collect and keep the longitudinal data necessary to perform studies of this nature. This seems to occur even in Great Britain (see footnote 17).

although only when accompanied by incentive regulation mechanisms (Estache, Perelman, and Trujillo, 2005, p. 8).[6]

Mota (2004), in contrast, compares the performance of 14 Brazilian privatized electricity distribution companies to the average performance of 72 U.S. investor-owned electric utilities, using data from 1994 and 2000, and finds that privatization had no statistically significant impact on efficiency when operating costs are used as an input, but resulted in a strong drop in efficiency for the models that used total costs. Mota's study finds that the Brazilian distribution companies experienced annual average productivity gains of around 5% during the period.

The present study of 52 Brazilian electricity distribution companies evaluates the efficiency evolution and the productivity gains that occurred in the sector from 1998 to 2003, checks for difference in performance between public and private firms, and examines the possibility of efficiency catch-up. It also investigates whether vertically integrated firms might be behaving strategically, shifting costs from unregulated to regulated activities, and whether efficiency changes are associated with variations in service quality.

The investigation provides evidence of performance improvement after the implementation of sector reforms, and finds that both privatized and public companies have reduced the efficiency gap with respect to companies that were privately owned before the reforms. The results show that privatized firms responded more aggressively than public firms to the new incentives brought by price-cap regulation. The findings also indicate a possible strategic behavior associated with the periodic aspect of price cap regulation, as well as to cost shifting

[6] Berg, Lin and Tsaplin (2005) also find that privatized firms respond differently to incentives than public firms. Their empirical analysis of 24 Ukraine electricity distribution companies from 1998 to 2002 indicates that privately-owned firms not only respond to incentives that add to net cash flows, but also respond more aggressively than do state-owned distribution utilities to cost-plus regulatory incentives that increase profits but decrease efficiency. The authors point out that comparisons of public and private utility performance need to be explicit about the incentive regimes facing both ownership types.

implemented by companies that operate in the electricity generation segment. Moreover, the paper suggests that the high performance improvement experienced by privatized firms in the period comes essentially from a more efficient operation of their units, in line with what was expected under an incentive regulation scheme, and not from mere reductions in costs brought by deterioration in the quality of service. Some of the results' implications for policy are highlighted, and it is underlined the possible use of the paper's findings to evaluate the regulator's decisions taken and methodology employed at the periodic tariff review.

The following section briefly describes the reforms undertaken in the Brazilian electricity sector. Section 3 discusses the technology of the electricity distribution industry, presents an overview of the different benchmarking techniques, provides a detailed picture of the stochastic cost frontier approach, and shows how exogenous factors that influence producer's performance may be incorporated into the analysis. The model specification and the data set are described in Section 4. Section 5 presents and interprets the results obtained, while Section 6 explores the possibility of strategic behavior and the relationship between observed efficiency changes and variations in service quality. The final section provides concluding observations and directions for future research.

Institutional Background

The power sector reforms in Brazil began in 1995. While constitutional amendments abolished the public monopoly over infrastructure industries and allowed foreign companies to bid for public concessions, the Law 8,987/95 (General Law of Concessions) set the stage for the beginning of the privatization process, represented by the auctions of Escelsa in 1995 and Light in 1996. By the end of 2000, a total of 20 distribution companies had been privatized.[7]

In addition, part of the implementation of a new regulatory framework involved the establishment of an independent regulatory agency (ANEEL) in late 1996 and, in the same year, the commission of an international consultancy to study and propose a new model for the electricity sector. The consultant's report was released in 1997 and its proposals were incorporated into Law 9,648, issued on May of 1998.[8] In essence, the approved model focused on privatization and unbundling of generation, transmission and distribution assets, gradual transition to a competitive generation environment in nine years, creation of a wholesale power market, operation of the transmission network by an independent operator, and use of the price-cap regime to regulate distribution tariffs, replacing the previous cost of service system.[9] This paper focuses on the distribution segment only. For the corresponding concessionaries, therefore, the sector reform changes which might have affected performance were privatization and the implementation of incentive regulation.[10]

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[7] Privatization concentrated on years 1997 and 1998, when nine and five firms where privatized, respectively. Only three firms had been privatized up to the end of 1996.

[8] See Ferreira (2000), Mota (2003), and de Oliveira (2003), for detailed descriptions of the new model's characteristics.

[9] With exception to companies Escelsa and Light, price cap regulation was implemented through the signature of new concession contracts, which took place from 1998 to 2000, and had their first tariff review scheduled for after five (for contracts signed in 1998) or four years. Light was the first to have price-cap regulation applied, by order of the concession contract signed in November/1996, in which the first tariff review was scheduled to occur after seven years. Escelsa was submitted to price-cap regulation in August of 1998, and had tariff reviews every three years thereafter. Except for Escelsa, all companies had the X factor set equal to zero in the first period prior to the first full review.

[10] Competition in electricity supply to high-voltage customers began only in 2004. Therefore, its possible effects on distribution firms' performance are not captured by the present study. On the other hand, distribution companies were affected by the unforeseen electricity crisis in 2001, caused by severe drought conditions and under investments in generation and transmission. The subsequent rationing measures proposed by the Government reduced significantly electricity consumption – and firms' revenues – in that year, and need to be controlled for in the analysis.

Methodology

The Electricity Distribution Technology

The modeling of electricity distribution technology is not straightforward. Many factors influence electricity distribution costs and, with respect to some of them, a controversy exists over their exogeneity.

Neuberg (1977) provided the theoretical foundations for the four factors that have been considered the main distribution costs' drivers. The higher the amount of kilowatt-hours sold, the greater the wear and tear on transformers, while increases in the number of customers induce higher meter-reading and billing expenses. The probability of a wire-outage is assumed as a monotonically increasing function of network length, and geographically dispersed areas, encompassing several cities, imply higher repair costs because of the greater labor input required by increased repair labor travel time, along with higher meter-reading and billing expenses.

Roberts (1986), on the other hand, emphasized the role of demand density (demand per unit of area), as a factor affecting scale economies and, consequently, the average cost of delivering a unit of power.[11] After noting that demand density can change if either the demands of existing customers change or new customers move into the service area, with the latter requiring customer-specific investments for the delivery of the product, the author argued for the inclusion of both factors (output density and customer density) in the model specification. Roberts' work also pointed out the multiproduct nature of the electricity distribution activity, with the consequent importance of treating low-voltage and high-voltage deliveries of power as

[11] The study finds that average distribution cost falls as output per customer increases, a result consistent with previous empirical studies' findings. According to Roberts, output density (output per customer) is useful for explaining not only differences in efficiency across companies but also differences within firms across time.

separate products, as well as the need to consider the percentage of more costly underground facilities on firm's total distribution equipment.

Some other distribution costs determinants are noted by Burns and Weyman-Jones (1996). Maximum demand determines the overall capacity of the system and at individual nodes, and together with energy delivered affects system load factor (reflecting the extent of peak use in the system). In addition, transformer capacity affects network losses. The type of customer, measured by the share of industrial KWh delivered, for example, determines the extent to which power lines operate at different capacities at different times, or the effect of delivering energy at different voltages. This same effect is sometimes captured by the load factor, used by Filippini and Wild (2001) in place of maximum demand, and defined as the ratio of average over maximum demand. The higher the load factor, the lower the average distribution costs, given the smaller fluctuations of electricity demand over time.

The way these factors should be incorporated in the analysis depends, initially, on the objective for the environment under study—output maximization or cost minimization. An important characteristic of the electricity distribution industry is that, in general, the concessionaries are required to provide service at specified tariffs. As a consequence, output is demand driven, with firms maximizing their profits by minimizing the cost of producing a given level of output. In this context, a cost function is the appropriate approach to deriving performance comparisons. This approach also has the advantages of being able to accommodate the multiproduct nature of the electricity distribution activity, and to treat variable and quasi-fixed inputs differently. The knowledge that some inputs are not variable during the period under study can be exploited by replacing a cost function with a variable cost function (Khumbakar and Lovell, 2000).

However, in a cost function approach, a measure of cost is modeled as a function of output(s) and input prices, leaving the question as to how all the above-mentioned factors that affect distribution costs can be incorporated into the function. Neuberg (1977), taking the separate marketability of components as a necessary property of a vector of outputs, argues that only number of customers and electricity delivered might be considered as outputs. Nevertheless, the other factors could be included in a cost function if they were taken as exogenous factors reflecting differences in distribution system from firm to firm (environmental variables).

The exogenous characteristics of some of the cost determinants listed above are subject to debate. Førsund and Kittelsen (1998) question the exogeneity of energy delivered and number of customers in a context where firms can decide upon their prices, which fortunately is not the rule on this regulated industry. The major concern involves network length and transformer capacity, which Fillipini and Wild (2001), among others, do not use as explanatory variables, arguing that they are capital inputs endogenous to the firm. These same factors are sometimes considered as fixed capital inputs in the short run, and consequently included as explanatory variables in a variable cost specification, such as those used by Salvanes and Tjøtta (1994), Burns and Weyman-Jones (1996) and Botasso and Conti (2003).

Moreover, Neuberg (1977) had already raised the point that the network length's exogeneity might come from taking it as a proxy for a linear measure of the territory, assuming a fixed geographic distribution of customers, whose importance is emphasized by Kumbhakar and Hjalmarsson (1998) in the context of sparsely populated countries, where, according to the authors, the amount of capital in the form of network reflects the geographical dispersion of customers rather than differences in productive efficiency.

An additional insight is provided by the empirical literature on comparative efficiency analysis. Jamasb and Pollitt (2001) survey this literature and report the frequency with which different input and output variables are used to model electricity distribution. Mota (2004) performs a similar task, but concentrates only on academic studies. Both surveys find that the most frequently used inputs are network length, transformer capacity and number of employees, and the most widely used outputs are units of energy delivered (with a high proportion of the studies decomposing it into high-voltage and low-voltage sales), number of customers and service area. Mota (2004) also reports that load factor, customer density, and output density are used as environmental variables in the studies surveyed.

Comparative Efficiency Studies

The increased emphasis on efficiency analysis has its origin in the implementation of incentive regulation. The adoption of incentive mechanisms aimed at improving the performance of companies formerly subject to rate-of-return regulation brought the need to measure the expected efficiency gains at the firm level, to be reflected in the X factor of a price-cap regime with an RPI-X rule.[12] In addition, the policy change stimulated research on whether the incentive mechanisms have effectively attained their performance improvement objectives.

In comparative efficiency studies, the estimation of an efficient frontier is the shared goal of the different methodologies. In all benchmarking methods, firm's efficiency is given by a measure of the distance of the observed practice to the efficient frontier. What differs is the technique for estimating the efficient frontier.

[12] The use of a comparative efficiency study with this purpose is subject to criticisms, however. Shuttleworth (2003) and Irastorza (2003), among others, argue that it provides misleading results, by confusing inefficiency with heterogeneity, and therefore should not be used.

A first possibility is to perform a bottom-up efficiency study, where the theoretical yardstick comes from the engineering knowledge of the industry process. This model (or theoretical) firm approach has not been the rule, but it was used in countries like Spain, Chile, Peru, and more recently by the electricity regulator in Brazil. Academic researchers have focused on estimating the efficient frontier based on an empirical estimate using observed data, with its estimation being implemented with either a parametric or a non-parametric technique.[13]

Non-parametric methods, like Data Envelopment Analysis (DEA), use mathematical programming techniques and do not require specification of production or cost functions nor the imposition of behavioral assumptions. These methods are generally easy to implement, but carry an implicit restriction in the number of variables that might be used, and do not allow for random shocks.

Parametric methods, in turn, entail applying an a priori functional form to the frontier, estimated with econometric tools. They allow for hypothesis testing,[14] enabling the analyst to investigate the validity of the model specification. Tests of significance can be performed for the functional form and for the inclusion or exclusion of factors, which is of special relevance for the electricity distribution industry, where the inclusion of several factors is theoretically justifiable. Moreover, with a parametric method it is possible to allow for stochastic factors or measurement errors, which avoids the assumption that all deviations from the best practice frontier involve inefficiencies.

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[13] For a detailed description of the different methods to perform efficiency analysis, and an assessment of the strengths and weaknesses of each, see Kumbhakar and Lovell (2000), Coelli, Prasada Rao, and Battese (1998), Cubbin and Tzanidakis (1998), Sarafidis (2002), and Atkinson et al (2003).

[14] In non-parametric models, a bootstrap technique may be used to produce confidence intervals around the estimated individual efficiency and thereby assess statistical properties of the efficiency scores generated (Simar and Wilson, 1998).

Thus, parametric methods can be deterministic or stochastic. A deterministic approach, like the Corrected Ordinary Least Square (COLS), does not allow for random shocks of elements beyond management control, which might have also contributed (positively or negatively) to the discrepancy between the individual firm performance and the frontier.[15] This problem can be addressed by using the so-called stochastic frontiers (Stochastic Frontier Analysis [SFA]), which use a mix of one-sided and two-sided error terms, with the former capturing the firm's inefficiency and the latter capturing the effects of random variation in the operating environment.[16]

Jamasb and Pollitt (2001), Mota (2004), and Estache, Perelman, and Trujillo (2005) perform comprehensive reviews of the comparative efficiency literature on the electricity industry, providing several examples of the use of the methods mentioned above to examine firms' performance.

In some of the existing studies, however, the choice of method was determined by ease of use or limited by sample size or data restrictions.[17] Ideally, the decision regarding the appropriate method depends on the purposes of the study and the context under examination. This study aims to investigate efficiency evolution through the period of 1998 to 2003, the decomposing of productivity growth for each firm into technical change and efficiency change, looking separately at public and private firms, and the degree of convergence in efficiency scores. The investigation, in turn, is conducted in an environment where random shocks were present and the

[15] Another drawback of COLS is that the structure of "best practice" production technology is the same as the structure of the "central tendency" production technology, since the estimated frontier is parallel to the OLS regression. Thus, the frontier does not reflect the production technology of the most efficient producers, but the one from producers down in the middle of the data (Khumbhakar and Lovell, 2000).

[16] The stochastic frontier approach is described in Section 2.3.

[17] For example, Pollitt (2005) reports that sample size and data limitations have restricted Ofgem's methodological choices and prevented the successful implementation of SFA and the incorporation of stochastic factors into the analysis of efficiency.

inclusion of several variables in the model specification, besides being theoretically justifiable, is advisable due to the high heterogeneity in operating conditions. These considerations lead to the use of a stochastic frontier approach, defined in terms of an input orientation, given the output exogeneity that characterizes the electricity distribution industry.

Stochastic Cost Frontier and Treatment of Environmental Variables[18]

A cost frontier can be expressed as

$$E_i \geq c(y_i, w_i; \beta), \qquad i = 1, \ldots, I, \tag{3-1}$$

where $E_i = w_i^T x_i = \sum_n w_{ni} x_{ni}$ is the expenditure incurred by producer i, $y_i = (y_{1i}, \ldots, y_{Mi}) \geq 0$ is a vector of outputs produced by producer i, $w_i = (w_{1i}, \ldots, w_{Ni}) > 0$ is a vector of input prices faced by producer i, $c(y_i, w_i; \beta)$ is the deterministic cost frontier common to all producers, and β is a vector of technology parameters to be estimated.

When the formulation above incorporates the fact that expenditure may be affected by random shocks not under the control of producers, the following stochastic cost frontier is obtained:

$$E_i \geq c(y_i, w_i; \beta) \cdot \exp\{v_i\} \tag{3-2}$$

Thus, the stochastic cost frontier consists of two parts: a deterministic part $c(y_i, w_i; \beta)$ common to all producers and a producer-specific random part $\exp\{v_i\}$, which captures the effects of random shocks on each producer. In this context, a measure of cost efficiency of producer i is given by

$$CE_i = \frac{c(y_i, w_i; \beta) * \exp\{v_i\}}{E_i} \tag{3-3}$$

[18] This section draws upon Kumbhakar and Lovell (2000).

which defines cost efficiency as the ratio of minimum cost attainable in an environment characterized by $\exp\{v_i\}$ to observed expenditure. $CE_i \leq 1$, with $CE_i = 1$ if, and only if, $E_i = c(y_i, w_i; \beta) \cdot \exp\{v_i\}$.

If it is assumed that the deterministic part $c(y_i, w_i; \beta)$ of a single-output cost frontier takes the log-linear Cobb-Douglas functional form, the stochastic cost frontier can then be written as

$$\ln E_i \geq \beta_0 + \beta_y \ln y_i + \sum_n \beta_n \ln w_{ni} + v_i \tag{3-4}$$

$$\ln E_i = \beta_0 + \beta_y \ln y_i + \sum_n \beta_n \ln w_{ni} + v_i + u_i \ , \tag{3-5}$$

where v_i is the two-sided random-noise component, and u_i is the nonnegative cost inefficiency component of the composed error term $\varepsilon_i = v_i + u_i$. The noise component v_i is assumed to be iid and symmetric, distributed independently of u_i. Thus, the error term $\varepsilon_i = v_i + u_i$ is asymmetric, being positively skewed since $u_i \geq 0$.

Under the above representation, a measure of cost efficiency of each producer i is provided by

$$CE_i = \exp\{-u_i\}. \tag{3-6}$$

Estimates of the production technology parameters, as well as of the cost efficiency of each producer, can be obtained with the maximum likelihood method, which requires that some distributional assumptions be made. While v_i and u_i must be assumed as distributed independently of each other and of the regressors, estimation of CE_i requires that separate estimates of statistical noise v_i and cost inefficiency u_i be extracted from estimates of ε_i for each producer, which, in turn, calls for distributional assumptions on the two error components. Therefore, by assuming that the two-sided random-noise component is normally distributed, and that the nonnegative cost inefficiency component follows a half-normal, an exponential, a truncated normal, or a gamma distribution, CE_i is obtained from the conditional distribution of u_i given ε_i.[19] More formally:

$$CE_i = E(\exp\{-u_i\}|\varepsilon_i) \tag{3-7}$$

It is worth noting that additional information might be provided when repeated observations on each producer are available. In a panel formulation, evidence of cost efficiency change can be obtained by including time as a mean inefficiency parameter, when a truncated normal distribution is assumed for u_i. On the other hand, the effects of technical change can be captured as well if time is included in the deterministic kernel of the stochastic cost frontier. When a translog functional form is adopted, that would amount to the inclusion of a time-trend (t) and its square (t^2) as additional regressors, obtaining:

$$\begin{aligned}\ln E_i = {} & \beta_0 + \beta_y \ln y_i + \sum_n \beta_n \ln w_{ni} + \frac{1}{2}\beta_{yy}(\ln y_i)^2 + \frac{1}{2}\sum_n \sum_k \beta_{nk} \ln w_{ni} \ln w_{ki} + \\ & \sum_n \beta_{yn} \ln y_i \ln w_{ni} + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + v_i + u_i\end{aligned} \tag{3-8}$$

Technical progress will be evidenced by a negative partial derivative of observed expenditure with respect to time. It should be stressed, however, that the inclusion of time in the manner depicted in Equation 3-8 accounts for what is known as *Hicks-neutral technical change*. This essentially implies that the cost frontiers (as production isoquants) are shifting each year but their slopes (e.g. the MRTS) do not change (Coelli, Prasada Rao, and Battese, 1998). *Non-neutral technical change* is obtained by also including terms involving the interactions of the other regressors and time.[20]

[19] See Kumbhakar and Lovell (2000, pp. 141-2) for the likelihood function and CE_i point estimator expressions.

[20] Likelihood Ratio tests might be employed to guide the decision upon which formulation should be used to account for technical change (neutral or non-neutral).

The stochastic frontier approach provides different ways to incorporate environmental variables, which exert an influence on producer performance in spite of not being inputs or outputs of the production process. The point deserves special attention in an efficiency analysis context, where it is essential to control for variation in producer performance due to variation in exogenous variables characterizing the environment in which production takes place. The way to proceed, however, depends on a previous judgment about how the interference of exogenous factors occurs. The environmental variables may influence the structure of the technology by which conventional inputs are converted to outputs, or they may influence the efficiency with which inputs are converted to outputs. In the first case, environmental factors should be included directly in the production or cost frontiers as regressors, producing efficiency scores which are net of environmental influences. In the second, these factors should be modeled so that they directly influence the inefficiency term.[21]

For this last case, one possibility is to assume a truncated normal distribution for the inefficiency error term and relax its constant-mean property, by allowing the mean to be a function of the exogenous variables (z_i). More specifically, $u_i \sim N^{+}(\mu_{it}, \sigma_u^2)$, with μ_{it} specified as

$$\mu_{it} = \delta_0 + \sum_{j=1}^{M} \delta_j z_{j,it} \qquad (3\text{-}9)$$

Another possibility is to relax not the constant-mean but the constant-variance property of the truncated (or half) normal distribution for the inefficiency error term, by allowing the

[21] This approach yields efficiency scores which incorporate the environmental effects. Coelli, Perelman and Romano (1999) call them "gross efficiency scores". The study proposes the substitution of $\sum_{j=1}^{M} \delta_j z_{j,it}$ in equation (3-9) for $\min[\sum_{j=1}^{M} \delta_j z_{j,it}]$, in order to obtain net efficiency scores. It is argued that the modification enables the efficiency measures to be estimated in a context where all firms are assumed to face identical conditions (i.e., the most favorable).

variance to be a function of the exogenous variables. According to Kumbhakar and Lovell (2000), this procedure makes it possible not only to incorporate exogenous influences on efficiency but also to correct for one possible source of heteroskedasticity. More specifically, $u_i \sim N^+(0, \sigma_{uit}^2)$, with σ_{uit}^2 specified as

$$\sigma_{uit}^2 = \delta_0 + \sum_{j=1}^{M} \delta_j z_{j,it} \tag{3-10}$$

In spite of being sometimes neglected in practice, the possible violation of the homoskedastic assumption requires special attention in parametric efficiency studies, since the consequences of heteroskedasticity are potentially more severe in stochastic frontier models, than in a classical linear regression model.[22] Heteroskedasticity can appear in either error component, as long as the sources of noise and/or inefficiency vary with companies' size, what is quite possible. While unmodeled heteroskedasticity in the symmetric noise error component (v_i) leads to biased estimates of technical efficiency, unmodeled heteroskedasticity in the one-sided inefficiency error component (u_i) leads to bias in both estimates of the parameters of the cost frontier and estimates of technical efficiency.[23]

The empirical literature on efficiency analysis provides examples of the use of these different approaches to account for environmental variables. Burns and Weyman-Jones (1996) and Estache, Rossi, and Ruzzier (2004) include these variables as additional regressors in the functions employed, Hattori, Jamasb, and Pollitt (2003) and Mota (2004) utilize the environmental factors to model the mean inefficiency, and Botasso and Conti (2003) employ them to model the variance of the inefficiency error term. There are also some studies that apply

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[22] If the error term is heteroskedastic in a classical linear regression model, estimators are unbiased and consistent, but not efficient.

[23] See Kumbhakar and Lovell (2000, pp. 115-122), for details on the direction of bias on estimates of technical efficiency caused by heteroskedasticity in either of the error components.

more than one of these approaches. Wang (2002) parameterizes both the mean and the variance of the inefficiency error term, to accommodate non-monotonic efficiency effects of exogenous variables. Coelli, Perelman and Romano (1999) and Hattori (2002), on the other hand, utilize models where environmental variables are first included as arguments of the input distance function and then as parameters of the mean inefficiency, comparing the specifications employed on the basis of the likelihood-ratio test. Both studies find that the sizes of the estimated efficiency measures differ significantly with the model selected, denoting that the methodological decision is a key point to be addressed in an efficiency analysis.[24, 25]

Specification and Data

In the present study, the sample was limited by availability of data and by the decision to exclude some very small concessionaries, which deliver less than 100,000 MWh per year. From the total of 64 electricity distribution companies in the country, nine were dropped from the sample due to small size and data for three others were unavailable. The unavailability of data also prevented the incorporation of the period before 1998 into the study. Therefore, the sample includes 52 companies, responsible for 99.47% of the total electricity delivered in the country in year 2003, with the data being collected for the period of 1998 to 2003. The data were assembled from the regulatory agency, the companies' websites, the financial statements provided to the Sao Paulo Stock Exchange, the Brazilian Association of Electricity Distribution Companies (ABRADEE), the Brazilian Institute of Statistics (IBGE), and the Caixa Economica Federal -

[24] Coelli, Perelman and Romano (1999) argue that, in the absence of a strong preference for one approach over the other, it is advisable to turn to the data for guidance.

[25] No matter which approach is adopted to control for environmental variables, some unobserved heterogeneity might still be embedded in the estimated efficiency measures. To address this point, Greene (2005a, 2005b) proposes a "true fixed effects model", in which firm fixed effects are included either as regressors or as parameters of the mean inefficiency, along with some environmental variables or not. This approach, though, might result in biased results if the number of repeated observations on each producer is small. In addition, the method forces any time-invariant inefficiency to be absorbed by the firm specific constant term, resulting in an underestimation of inefficiency.

CEF, a public financial institution that is in charge of most of the social programs of the federal government and provides financing to house construction projects.

One of the companies in the sample (Elektro) resulted from a split that occurred in January of 1998. Consequently, its data for that year were not used. Another company (Bandeirante) was split in 2001. The company's data for the year 2001 was disregarded, and the resulting two companies were treated as new firms in the sample (after 2002). As a result, the sample has 50 firms in 1998, 51 in 1999 and 2000, 50 in 2001, and 52 firms in 2002 and 2003.

Among the sample companies, 23 were publicly owned in the beginning of 1998. Seven of them were privatized during the period examined (four in 1998, one in 1999, and two in 2000). For the purposes of this study, a privatized company was considered "Private" in the same year it was sold only if the privatization occurred before June 30th. Therefore, there were 21 publicly owned distribution companies in 1998, 19 in 1999, 17 in 2000, and 16 from 2001 to 2003.

We use a variable cost specification, given our belief that transformer capacity and network length constitute capital inputs that are fixed in the short run, and provide important information in terms of system configuration. In addition, environmental variables are included as arguments of the variable cost function, instead of as mean inefficiency parameters, as we are interested in having efficiency indexes net of factors exogenous to the firms.[26]

We turn to the stochastic frontier's hypothesis testing capabilities to guide our decision regarding the functional form, the incorporation of technological change, and the distributional assumption for the inefficiency error term. Likelihood ratio tests rejected not only the Cobb-Douglas functional form in favor of the translog, but also the Hicks-neutral formulation of

[26] It should also be stressed that the specification employed provided a better fit than the one where the environmental variables entered as mean inefficiency parameters, according to the Likelihood-ratio tests that were performed comparing these two alternative ways of treating environmental variables against a nested model.

technical change in favor of the non-neutral formulation. Moreover, the tests supported the half-normal distribution for the inefficiency error term, compared to the truncated-normal distribution.[27]

In light of the pronounced heterogeneity among the companies in the sample, in terms of size and customer structure,[28] we checked for the presence of heteroskedasticity on the two error components. The null of homoskedasticity was supported for the two-sided noise component (v_i), but rejected for the one-sided inefficiency error term (u_i). As a result, in our model the variance of inefficiency error component is conditioned on a proxy of firm size, given by total electricity delivered (Q).

Hence, the specification adopted is shown in equation 3-11[29]

$$\begin{aligned}\ln E_{it} = {} & \beta_0 + \beta_y \ln y_{it} + \sum_n \beta_n \ln w_{nit} + \frac{1}{2}\beta_{yy}(\ln y_{it})^2 + \frac{1}{2}\sum_n\sum_k \beta_{nk} \ln w_{nit} \ln w_{kit} + \sum_n \beta_{yn} \ln y_{it} \ln w_{nit} \\ & + \beta_c \ln Cap_i + \beta_l \ln Len_i + \sum_j \beta_j \ln Z_{jit} + \beta_t t + \beta_{yt} \ln y_{it} t + \sum_n \beta_{nt} \ln w_{nit} t + \frac{1}{2}\beta_{tt} t^2 + v_{it} + u_{it}\end{aligned} \tag{3-11}$$

where E and y are the cost and output measures, respectively, W is the vector of factor prices, *Cap* stands for transformer capacity, *Len* represents network length, Z is the vector of environmental variables, and it is assumed that $v_{it} \sim N(0, \sigma_v^2)$ and $u_{it} \sim N^+(0, \sigma_{uit}^2)$, with σ_{uit}^2 specified as

$$\sigma_{uit}^2 = \varphi_0 + \varphi_Q Q_{it}$$

[27] The null hypothesis that the mean of the inefficiency error term distribution is equal zero was not rejected, even at the 10% significance level.

[28] This point is detailed in the interpretation of the descriptive statistics, presented below.

[29] The decision to not use a multiple output formulation, where outputs would be defined in terms of electricity delivered to low-voltage customers and to high-voltage customers, was due to the inclusion of share of electricity delivered to industrial customers as an environmental variable. The alternative specifications were compared, with the one employed in the present study providing a better fit.

The modeling of technical change in the way shown in equation 3-11 is used to get evidence of technological change over the period considered. For the computation of firms' efficiency indexes and the consequent analysis of efficiency change, however, we turn to the use of time fixed effects, to control for possible changes in macroeconomic factors that might have affected firms' performance during the period under investigation. In the present study, it is important to avoid attributing to efficiency change variations in cost caused by other phenomena, such as industry-wide technological advances and changes in interest rates, exchange rates or electricity sector policy. Note that the use of time fixed effects explicitly allows the computation of efficiency indexes relative to yearly-specific frontiers.

The evolution of firms' performance (efficiency change), the possibility of differential performance between private and publicly owned firms, and the existence of a privatization effect on firms' efficiency are investigated with a conditional mean specification, where the following variables are included as parameters of the mean inefficiency error term: (a) indicators of time (time trend and its square); (b) a private dummy (*PRIVATE*); and (c) two other indicator variables representing companies that were privatized (*PRIVTZED*) and the ones that were already private before the beginning of the privatization process (*ALWSPRIV*). Additional insights on efficiency evolution are supplied by the analysis of average inefficiency scores and mean relative cost inefficiency measures, computed for each year in the period of 1998 to 2003, which also enables the investigation of the possibility of efficiency catch-up over the period.

The observed technological change (ΔTC) and technical efficiency change (ΔTE) are then combined to provide a more complete picture of the productivity improvements occurred in the period under examination. This is done through the computation of Malmquist productivity indices, following the methodology proposed by Coelli, Prasada Rao, and Battese (1998) for stochastic frontier methods, adapted to a cost frontier context. For each firm, the Malmquist index of productivity change between two consecutive periods is given by

$$MI_j = \Delta TE_j \cdot \Delta TC_j$$

where

$$\Delta TE = -\left\{ \left(\frac{Eff.Index_{j,t+1}}{Eff.Index_{j,t}} \right) - 1 \right\} + 1 \qquad \text{and} \qquad \Delta TC = \left\{ \left(1 + TC_{j,t}\right) \cdot \left(1 + TC_{j,t+1}\right) \right\}^{1/2}$$

The resulting measures of productivity change, along with their decomposition into productivity catch-up (ΔTE) and frontier shift (ΔTC) components, are employed to compare the performance of firms by ownership type.

In our model (equation 3-11 above), the dependent variable is given by the operating costs of distribution and retail service activities (Opex), computed as the sum of labor, materials and third party service contracts expenses, as reported in the income statement.[30, 31] Electricity delivered, in MWh (Q), is the output measure[32] and average wage, calculated as total labor expenditure divided by the number of employees, is used as a proxy for the price of labor (LP).[33] For the prices of materials (MP) and third party services (SP), the work uses two price indexes provided by IBGE and CEF. The materials' price index reflects the observed change in the price of a basket of items used in civil construction, by State, while the third party service's index

[30] The computed labor expenses include firms' contributions to pension funds and to health insurance plans, profit sharing payments, and management wages. Some firms already report these expenses under the classification of labor expenses, but most of them do not. The necessary adjustments were made on these cases.

[31] In case of vertically integrated companies, the computation of the operating costs of distribution and retail service activities was made possible by the fact that those companies are required by law to report their expenses separated by activity.

[32] The use of two measures of output was prevented by the fact that electricity delivered and number of customers showed up as highly collinear, with one of them being always dropped by the statistical software employed (Stata). A better specification was provided by the former, when compared to the latter.

[33] Total labor expenditure is employed to compute average wage because it was not possible to obtain information related to number of employees segregated by sector activity, for the cases of firms that also operate on generation and transmission.

portrays the observed change in the salaries paid to an electrician, also by State. The variables Opex, LP, MP, and SP are expressed in 1998 values, being deflated by a general price index (IGP-DI).

The regulatory agency does not keep track of changes in transformer capacity and network length of each distribution company over time. However, information on these variables was needed for the periodic tariff review, and gathered in year 2002. It is worth noting that by employing these data on the present study we are implicitly assuming that both variables remained constant during the whole period under examination, despite the observed increases in output and in the number of connections.[34] Notwithstanding the possible stringency of this assumption, the variables were kept in the model due to their observed importance in explaining variation in operating costs among firms, as is mentioned in the next section. Transformer capacity is given in MVA, and network length corresponds to the sum of high-voltage and low-voltage lines, in kilometers. Since these variables showed up as highly correlated with electricity delivered, the variables Cap and Len in our specification (equation 3-11) actually correspond to the residuals of the regression of transformer capacity on electricity delivered and network length on electricity delivered, respectively.

Particular attention was given to incorporating exogenous factors that could control for differences in firms' operating conditions, given the heterogeneity that characterizes the Brazilian electricity distribution industry, as well as our interest in having efficiency measures net of factors that impact firms' performance but are out of control of the concessionaries. After checking the significance of their influence on firms' technology (as cost frontier shifters) and on

[34] The companies in the sample experienced an increase of 23% in the number of customers, from 1998 to 2003. Electricity delivered by these firms, on the other hand, increases 7.6% from 1998 to 2000, and 2.1% from 1998 to 2003.

firms' efficiency (as mean inefficiency parameters)[35], the following environmental variables were included in the modeling: customer density (CusDen), given by number of customers divided by network length; share of electricity delivered to industrial customers (IndShare); residential density (ResDen), computed as electricity delivered to residential customers divided by the number of residential customers; service area[36] (Area), in Km^2; ratio of underground to overhead lines (Undergrd); and income per capita, by State (Income), to control for variations in socio-economic conditions among States.

Descriptive statistics are shown in Table 3-1. The difference between minimum and maximum values of observations collected for almost all variables used indicate the considerable heterogeneity among firms in the sample, in terms of companies' size, system configuration, and customer structure. Electricity delivered, for example, varies from 103,191 to 37,540,051 MWh, while the share of electricity delivered to industrial customers ranges from 3 to 64%, and transformer capacity fluctuates in the interval of 120 to 22,728 MVA. The evidenced disparity in firms' indicators corroborates the need to account for external factors in the comparative efficiency analysis.

It is observed, from the evolution of the variables' mean values, that operating costs drop around 26%, in real terms, from 1998 to 2003.[37, 38] This reduction is partly due to the falling

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[35] The six environmental variables included in our specification showed up as statistically significant mean inefficiency parameters. The results indicated that firms' efficiency increases with *IndShare*, *ResDen*, and *Income*, and decreases with *CustDen*, *Area*, and *Undergrd*.

[36] The Brazilian case justifies the inclusion of both network length and service area in the modeling and this is reflected in the statistical significance of both variables as either cost shifters or mean inefficiency parameters. While some companies have small service areas and relatively high network length (the ones that operate in the more densely populated states), others have high *Area* but relatively low *Len*, because they operate in states which are more sparsely populated and/or have a high share of the population not being served.

[37] The indicated variation, as well as all others based on the numbers portrayed in Table 3-1 and mentioned in this section, is adjusted for the change in the number of firms in the sample from year to year.

prices of materials and third party services, which fell 12.9% and 21.9%, respectively, in the same period. It is also interesting to note the dramatic reduction in electricity delivered that occurred in 2001 (-7.6%), as a consequence of the rationing imposed by the government. The volume of electricity delivered increased in 2002 and 2003, but it still was, in 2003, smaller than the volume delivered in 1998, and 5.1% less than the amount delivered in 2000.

The same "rationing effect" is observed in the average residential consumption, which decreased 13.8% in year 2001. This indicator, however, does not recover in years 2002 and 2003 (it is even slightly smaller on these years). This fact, which may be due to higher electricity prices in the post-rationing period, might also indicate a shift in the residential customers' demand for electricity, as a result of a change of habits induced by the rationing measures.[39]

Findings

Prior to estimation, all variables were normalized by their sample median values. Additionally, in order to ensure homogeneity of degree one in prices, the dependent variable and the factor prices were normalized by the price of third party services. The models are estimated by maximum likelihood, using the Stata 9 software.

Table 3-2 provides the results from the models estimated, while the elasticities of operating costs with respect to output, factor prices, and time are reported in Table 3-3. It is observed that the estimated cost function satisfies the monotonicity condition with respect to output and factor prices at the mean. Moreover, as was expected, operating costs are negatively affected by

[38] The higher drops occur from 1998 to 1999 (-14.1%), and from 2000 to 2001 (-9.5%), year in which there was the energy rationing. Mean operating costs are also reduced by 5.7% from 2001 to 2002.

[39] From 2001 to 2003, the number of residential customers of the sample firms increases from 38,160,276 to 42,237,897, with the amount of electricity delivered to this group of customers going from 66,399,207 MWh to 70,824,904 MWh. This volume of electricity was still smaller than the one observed in 2000 (75,283,460 MWh), when there were 36,816,473 residential customers. Thus, the already existing residential customers in year 2000 consumed, in that year, more electricity than in year 2003. The numbers above are adjusted for the change in the number of firms in the sample from year to year.

increases in the share of electricity delivered to industrial customers, and positively affected by increases in electricity delivered, service area, factor prices, share of underground facilities, and customer density. Note also that transformer capacity and network length show up as statistically significant (at the 1% level) variables explaining variations in operating costs among firms. As capital proxies, their positive coefficients met our expectation.

The income per capita coefficient estimate is negative and significant, which might be reflecting higher maintenance costs incurred in low-income areas and, possibly, the impact of work force qualifications on firms' productivity. Furthermore, the positive and significant coefficient on Q as a variance parameter indicates that variations in firms' inefficiency levels increase with firm size.

The time elasticity provides a measure of technological change. The results show that there was technological progress during the sample period, with an annual rate of technological change of around 6.55%, on average, which denotes that the efficient frontier has shifted considerably from 1998 to 2003. Note also that the estimated coefficient on the squared term of time is negative, indicating that the observed rate of technological progress has increased through the period examined.

We investigate the possibilities of differences in technology and in the rate of technological change between public and private firms through the use of a private dummy and an interaction term private*time. The negative and significant private dummy coefficient (see Model "B" in Table 3-2) indicates that private firms have had a better technology. This conclusion, however, should be taken with caution, since the dummy captures the effect of any systematic difference between the firms' groups, which might include a difference in firms' performance.

The results also show a slightly higher rate of technological change for public firms, when compared to their private counterparts. Nevertheless, when private firms are separated into privatized and not privatized firms (called “always private”), it is observed that the above mentioned relationship holds only for the comparison of public and “always private” firms, since the privatized companies actually had a higher rate of technological change than the public companies (Model “C” in Table 3-2). These results are corroborated by the information provided in Table 3-4, where the technological change observed in the period is segregated by year and firms’ ownership type.

Firms’ efficiency indexes are computed on the basis of the time fixed-effects specification. An indication of efficiency evolution throughout the period and of comparative performance of public and private companies is provided by the results of the conditional mean inefficiency model (Models “E” and “F” in Table 3-2). The coefficient on the time variable is negative, but not significant, suggesting that efficiency improves only slightly over the period. On the other hand, the results indicate that private firms, specifically the privatized ones, are significantly more efficient than public firms in the period examined.

A more detailed picture is seen in Table 3-5, which reports average inefficiency scores and mean relative cost inefficiency measures, computed for each year in the period of 1998 to 2003 and discriminated by firms’ ownership type. The relative cost inefficiency was obtained by dividing each firm’s inefficiency score by the minimum score observed in each year.

The efficiency improvement is reflected in the reduction of average inefficiency scores in the period. On average, efficiency increases 1.51% from 1998 to 2003. The efficiency gains are followed by a concomitant reduction in dispersion of efficiency scores, with the standard deviation going from .0999 in 1998 to .0697 in 2003, constituting evidence of a catch-up effect.

This evidence is corroborated by the mean relative inefficiency measures. While in 1998 the distribution companies were, on average, 8.7% more inefficient than the most efficient company in that year, in 2003 they were only 6.3% more inefficient than the most efficient distribution utility. This indicates that the observed efficiency improvement comes, essentially, from companies that were relatively inefficient in the beginning of the period.

Additional insights are obtained when one looks at the evolution of these measures for public and private firms separately. Here, to avoid possible distortions in the efficiency evolution analysis resulting from the privatizations occurred in the period[40], the average inefficiency and the mean relative inefficiency measures computed for public firms reflect only the performance of the 16 firms that remained public up to 2003.

Notice first that in the beginning of the period the group of private companies which did not go through a privatization process is more efficient, on average, than both the public and the privatized companies' groups.[41] In addition, the public firms' mean inefficiency measure is slightly inferior to the privatized firms' measure[42], indicating that the privatization process did not concentrate initially on the most efficient public firms.[43]

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[40] For example, if the public companies that turn out to be privatized in years 1998 to 2000 performed differently than the average public companies in that period, an analysis that do not take these firms into account would compare average public firms' scores for years 2001 to 2003 to distorted average public firms' scores for years 1998 to 2000.

[41] According to one-sided mean comparison tests performed, "always private" firms' mean inefficiency in 1998 is significantly lower than both public firms' mean inefficiency (p-value = .0291) and privatized firms' mean inefficiency (p-value = .0192).

[42] The null of no difference in mean inefficiency of public and privatized firms was not rejected, even at the 10% level. The p-value of the alternative hypothesis that privatized firms' mean inefficiency is greater than public firms' mean inefficiency was equal to .3517.

[43] This is the same to say that the hypothesis that it is efficiency that leads to privatization, and not the reverse (which Bagdadioglu, Waddams Price, and Weyman-Jones (1996) claim to have found some support for in the Turkish case), is not supported in the present context. This fact, however, does not rule out the possibility of endogeneity of privatization decisions, a point that we address later.

In line with what was mentioned before, the information in Table 3-5 shows that both the efficiency improvement occurred in the sector and the identified catch-up effect come, essentially, from the performance of privatized firms, which experience an increase in mean efficiency of 5.58% from 1998 to 2003, associated with an expressive reduction in dispersion of efficiency scores. Public firms' mean efficiency increases only 0.35% in the same period, while the same measure for "always private" firms decreases almost 3%.

We have identified, among the privatized companies, the ones that were privatized after June/1998, since their corresponding 1998 efficiency scores are free of any privatization effect. It is interesting to observe that these firms experience an average efficiency increment of 7.8% from 1998 to 2003[44] (Table 3-6), much higher than the obtained by the ones that remained publicly owned. Furthermore, it is worth noting that the decrease in "always private" mean efficiency in the period under exam comes, essentially, from the deterioration on these firms' performance from 2002 to 2003, confirmed by a one-sided mean comparison test, which rejected the null hypothesis of equality of mean inefficiency scores on the two periods, at the 1% significance level.[45] We will return to these points later.

The rates of technological change and of efficiency change, observed between two consecutive years, are combined to provide a measure of productivity change, given by the Malmquist indexes reported in Table 3-7. The results indicate that the Brazilian electricity

[44] Some companies were privatized in 1999 and 2000, but their efficiency improvement in the period before the privatization was not representative. It corresponded to only 8.4% of the above mentioned efficiency increment in the period of 1998 to 2003.

[45] The same null hypothesis of equality of mean inefficiency scores (of "always private" firms) was also rejected for years 2000 and 2001, at the 5% significance level, and supported for all other consecutive periods.

distribution industry's productivity increased 38.5%, on average, from 1998 to 2003.[46] In addition, productivity growth rates are increasing throughout the period and come, essentially, from frontier shifts (37%), with a relatively small catch-up effect for the sector as a whole (1%).

The computed mean productivity growth rate of 6.73% stands out when it is compared to the 0.9% mean total factor productivity growth rate of the economy found by Gomes, Pessôa, and Veloso (2003) for the period of 1992 to 2000.[47] Moreover, taking the results found by Mota (2004) as a proxy for the distribution companies' average productivity gains in the period of 1994 to 1998 (around 5%)[48], it might be concluded that the sector's rate of productivity growth increased after 1998.

The observed increment in the sector's productivity comes from the performance of privatized and public firms, which experience productivity growths of 57.2% and 39.2%, respectively, from 1998 to 2003, against a productivity growth of only 16.1% of the "always private" firms (Table 3-8). These results, taken together with the ones previously mentioned, constitute evidence that the high productivity gains observed in the period of 1998 to 2003 are associated to the closing of the efficiency gap present in 1998. Both the firms that were privatized and the ones that remained publicly owned have decreased the difference in performance with respect to the "always private" firms' group, with privatized firms actually surpassing the "always private" firms' efficiency level.

[46] The above mentioned measure of productivity change does not incorporate the scale effect. On the basis of the computed output elasticity and the actual changes in output from year to year, we have estimated it to be equal to 3.56%, on average, from 1998 to 2003.

[47] The authors report that their result is consistent with the findings of two other studies that examined the subject.

[48] Mota obtains annual average productivity gains of about 5% in the period of 1994 to 2000 using data only from these two years and from 14 privatized companies. Considering that the present study provides evidence of significantly higher privatized firms' productivity gains for the period of 1998 to 2000, Mota's result can be taken as an upper-bound measure for average productivity gains in the period of 1994 to 1998.

Note that public firms' efficiency has indeed improved significantly from 1998 to 2003. The performance improvement, however, is not reflected in better efficiency indexes (public firms' mean efficiency increase only 0.35% in the same period), or in a positive catch-up effect (Table 3-8), due to the higher improvement of privatized firms' performance. Efficiency analysis is comparative and dynamic. Public firms have essentially kept the same distance to a frontier that has shifted considerably during the period, mainly in response to productivity gains of privatized companies.

Looking at possible motivating factors for these findings, and in particular at privatization and the implementation of incentive regulation, it must be stressed, at first, that in the present study it is not possible to precisely assess the fraction of productivity improvement due to the adoption of the price-cap regime, and neither if there is effectively a causality relationship on this respect, given the lack of data from the period pre-reforms and the absence of a "control group". Furthermore, it must be recognized that, despite the use of time fixed effects, other concurrent factors may have impacted the results, by affecting some firms and not others. Distribution companies with a high exposure to financing in dollar[49], mainly some of the privatized ones, might have had to cut costs and be more productive to compensate the higher expenses brought by the real devaluation in 1999, whereas some public companies may have had to do the same to put an end in the series of negative profits which became unsustainable in a context of increasing State budget constraints.

However, no matter the specific reason that has induced each firm to expend some effort to improve its performance, it might be conjectured that this action only took place because the

[49] The real devaluation also impacted the amount distribution companies had to pay for the energy bought from Itaipu. However, given that these expenses were considered non-controllable costs and, consequently, entirely passed on to the tariffs, I do not consider them as an efficiency improvement inducing factor.

price-cap regime provided the conditions and incentives for it to happen, which would not be present in a rate-of-return regulation context.[50] In this sense, the observed increase in firms' productivity growth, over the mean productivity growth rate found by Mota (2004) for the period before 1998, could be associated with the implementation of incentive regulation.

This association is corroborated by the finding that productivity gains increase throughout the period, which is consistent with the progressive implementation of incentive regulation in Brazil.[51] The increasing productivity gains may also result from the fact that the labor force reductions implemented by many firms which began to operate under incentive regulation may actually increase short term labor costs. Labor force reductions are typically achieved by paying employees to terminate their employment voluntarily, and the associated expenditures are recorded as short term costs (Kridel, Sappington, and Weisman, 1996).

It should also be noted that most of those firms regarded as more inefficient at the beginning of the incentive regulation scheme have experienced very high productivity gains, in line with the regulator's expectations. Given the similarity in the two firm groups' efficiency levels in the beginning of the period, the performance of firms which remained publicly owned can be taken as a proxy for the performance that privatized firms would have had if they had remained public. Consequently, the difference of almost 18% in productivity growth from 1998 to 2003, which is equivalent to a (geometric) mean productivity growth rate of 3.36% per year, constitutes a measure of the privatization effect. It also provides evidence that privatized firms have responded more aggressively than public firms to the efficiency improvement incentives

[50] This assertion comes from the fact that in rate-of-return regulation revenues are linked to realized costs. Hence, in the usual situation of a one-year regulatory lag, it is expected that the regulated company will not have an incentive to make a costly effort to reduce costs because possible higher profits in the current period have to be balanced against lower revenues in all subsequent periods.

[51] See footnote 9.

brought by the price-cap regulation, implying that incentives were higher for profit-oriented managers operating under a shareholders' pressure to quickly recoup investments.

The analysis, however, has to account for the possibility of endogeneity of privatization decisions. The mean comparison tests performed revealed that privatized firms, on average, have a bigger size and a higher share of industrial customers than public firms[52], which is consistent with the hypothesis that companies with a higher potential for performance improvement were the ones selected to be privatized. To address the topic, a new performance comparison was implemented using a more homogeneous group of firms, given by the ones with *Q* higher than 400,000 KWh per year.[53] With the new sample, although the computed Malmquist indexes indicate a smaller productivity improvement for all firms over the period, compared to the one obtained previously (Table 3-8), the difference in productivity growth between privatized and public firms is even higher than the one found before (29% against 18%). This result corroborates the conclusion that privatized firms responded more aggressively than public firms to the price-cap incentives.

Conversely, the difference in productivity growth rate of these two firm groups provides an indication of the additional improvement in performance that public firms might have obtained. In light of the distributional consequences of these not-implemented-but-achievable productivity gains, in the sense that they could have resulted in lower tariffs to customers, the issue is of

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[52] Privatized and Public firms were compared in terms of any variable used in the estimation procedure. The null of equality of means was rejected for the variables *Q*, *NumCust*, *Cap*, and *IndShare*, with privatized's mean showing up as greater than public's mean in all these cases.

[53] Five out of the fifteen biggest distribution companies are publicly owned. Due to the new criteria, fifteen firms were dropped from the initial sample (5 public, 1 privatized, and 9 always private). And when public and privatized firms were compared using data from the new sample, the null of equality of means was rejected only for the variables *LP* (Public > Privatized) and *IndShare* (Public < Privatized). The two groups of firms do not differ in size anymore.

particular relevance for the regulator, who needs to target the appropriate efficiency improvement incentives to this group of firms.

The electricity regulator has had the opportunity to act on this matter in the periodic tariff review that started in April 2003. It is of interest, therefore, to evaluate the regulator's decisions on this occasion, notably with respect to their consequences in terms of both distribution of productivity gains among stakeholders and incentives for further efficiency improvements. Such evaluation should not be restricted to the specific case of public firms, though, since its insights are equally valuable in the case of the other distribution companies. It is important to note what was done with respect to companies that have experienced lower productivity gains in the period, such as the "always private" ones, and, by virtue of its signaling effect to all concessionaries, whether privatized firms' productivity gains in the period were completely passed on to the new tariffs.[54]

"Always private" firms were more efficient, on average, than the other distribution companies in 1998, and have experienced, from 1998 to 2003, a productivity growth higher than the mean total factor productivity growth rate of the economy found by Gomes, Pessôa, and Veloso (2003) for the period of 1992 to 2000 (3.04% and 0.9%, respectively). Hence, their performance in the period might be taken as consistent with what was expected under a price-cap regime in view of their initial efficiency lead over other distribution companies and of the fact that the efficiency analysis performed in this study does not incorporate changes in capital expenditures.[55]

[54] I am currently working on these points in another paper.

[55] Under rate-of-return regulation, firms have an incentive to overinvest in capital, moving away from the optimal capital/labor ratio. Note that these firms will probably show up as relatively efficient if the performance analysis is based on operating expenses only, as is the case in the present study. In this context, when price-cap regulation is implemented, the prospect for efficiency improvements in operating and maintenance expenses is limited.

The results found for this group of firms might also be related to the fact that they operate at a lower scale, with lower potential for efficiency improvements.[56] Note, however, that the observed decline of these firms' mean efficiency levels[57] derives from their low productivity growth in 2003, which is 23% less than the average of their productivity growth in the four years before (Table 3-9). The deterioration in performance might have been caused by the need to accomplish some regulatory requirements, such as the ones related to service quality (a point addressed in the next section). Nonetheless, it cannot be ruled out a possible strategic behavior of some of these firms, which could have inflated costs near the time of the periodic tariff review in order to obtain higher repositioning indexes and, consequently, higher allowed revenues for the subsequent tariff period.[58, 59]

Service Quality and Economies of Vertical Integration

Two additional points are investigated. First, in view of the well-known concern that price-cap regulation may provide incentives to reductions in quality of service, it is examined if there is an association between efficiency and service quality in the Brazilian electricity distribution

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[56] When always private firms were compared to other firms, the results from the mean comparison tests revealed that Always Private's mean values were significantly higher than Public or Privatized's mean values for the variables *SP* and *Income*. On the other hand, Public or Privatized's mean values showed up as significantly higher than Always Private's for the variables *Opex, Q, NumCust, LP, Area, Cap, Len, Undergrd*, and *CusDen*. In essence, Always Private firms are of a considerable smaller size than other firms, and operate in smaller service areas.

[57] As mentioned before, "always private" mean efficiency score decreases almost 3% in the period, with the most significant change occurring from 2002 to 2003, according to the results of the mean comparison tests performed.

[58] Although firm's own operating costs were not considered directly in the definition of the repositioning index, under the reference company approach adopted by Aneel, a firm that artificially inflated its costs in the period near the tariff review would be acting in order to increase its bargaining power in the tariff review process. The rationale is that the probability of a firm request to increase its estimated efficient operational costs be accepted by the regulatory agency increases with the difference between estimated and "real" (informed by the firms) costs.

[59] This type of regulation game, associated with the periodic aspect of incentive-based regulation, is known to regulators and was reported in the survey conducted by Jamasb, Nillesen, and Pollitt (2003). Evidence of strategic behavior of the same sort was found by Di Tella and Dyck (2002), in a study of the Chilean electricity distribution utilities. The study reports U-shaped cost reductions associated with the introduction of price cap regulation, with strong initial cost reductions reversing every four years, coinciding with regulatory reviews.

sector. [60] Beyond that, it is checked whether the variations in efficiency levels identified in the present study may result from changes in service quality. Secondly, given that some distribution companies in the sample also operate in generation and transmission, it is investigated the presence of economies of vertical integration and, as a corollary, the possible occurrence of firms' strategic behavior.

Vertically-integrated companies generally experience economies of scope, which would help them be more efficient than other concessionaries.[61] They also have the opportunity to behave strategically, classifying expenses incurred in their generation and transmission activities as costs pertaining to the regulated distribution activity.[62] In this context, a finding that vertically integrated firms are significantly more inefficient than other distribution companies, despite plausible economies of scope, would indicate that cost shifting may be occurring.

The 14 companies that generated at least 10% of the electricity they delivered to final customers in 2003 are considered vertically integrated.[63] Service quality is measured on the basis of two continuity of service indexes implemented by the regulator, DEC and FEC, associated with duration and frequency of service interruptions, respectively. While the DEC index

[60] Actually, as it is stated by Ai, Martinez, and Sappington (2004), economic theory does not provide unequivocal predictions regarding the effects of incentive regulation on service quality. When authorized revenues are not tied directly to realized costs, a regulated firm may be tempted to reduce service quality in order to reduce costs, and thereby increase profit. On the other hand, because incentive regulation can allow a firm's revenue to rise substantially above realized costs, incentive regulation may motivate the firm to improve service quality in order to enhance the demand for its products and thereby increase revenue. Nonetheless, given that in the electricity distribution sector the demand is essentially exogenous to the firm, especially when there is no competition, it is possible to argue that the first effect should prevail over the second in this specific context.

[61] See Lowry and Kaufmann (1999), for details about economies of vertical integration in the power distribution sector.

[62] The rationale for this behavior is provided by Joskow (2005). In light of the uncertainties the regulator faces about the firm's inherent cost opportunities, the firm would like to convince the regulator that it is a higher cost firm than it actually is, in the hope that the regulator will then set higher prices for the services it provides as it satisfies the firm's long run participation constraint, increasing the regulated firm's profits, creating dead-weight losses from prices that are too high, and allowing the firm to capture surplus from consumers.

[63] Among the vertically-integrated firms, six are publicly owned and five are privatized companies.

measures the number of days of service interruption within a period, the FEC measures the total number of service interruptions within a period. Note that service quality is inversely related to DEC and FEC values. The service quality variable (*Quality*), therefore, is given by the inverse of the equally weighted average of the continuity of service indexes.[64, 65]

A severe missing observation problem was identified with respect to DEC and FEC data for 1998. Thus, *Quality* measures for each firm in the sample were computed for the period of 1999 to 2003. The mean values of DEC and FEC indexes, as well as of the resulting *Quality* variable, are displayed in Table 3-10, which shows that the continuity of service indicators improved substantially over the period, resulting in an increase of almost 50% in the computed *Quality* variable from 1999 to 2003. The numbers portrayed provide an indication of the effectiveness of quality regulation instruments implemented by the regulator.

The *Quality* decomposition by firm group reveals that the mentioned increase in service quality was driven by privatized and always private firms, whose *Quality* measures raised 54.6% and 51.6%, respectively. It also shows that the lower service quality improvement experienced by public firms (35.7%) resulted in an increase in the distance of these firms to the others in terms of quality of service provided to customers. It must be stressed, however, that in light of the rather different operating conditions experienced by these groups of firms, the continuity of service indicators incorporate factors out of firms' control and, consequently, cannot be taken

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[64] I recognize that some important dimensions of service quality are not incorporated in the *Quality* measure, such as those related to customer satisfaction, the speed with which reported problems are resolved and the intrinsic quality of the product offered to customers, an inverse function of variations in electricity tension levels. The *Quality* measure, however, captures the adequacy of system maintenance, the amount of human and capital resources allocated to network restoration and repair, and the existing facilities to recuperate the system after each interruption (vehicles, communication, qualification of the work force, etc.).

[65] In the Brazilian electricity distribution sector, quality regulation and enforcement have essentially been done through the definition of target DEC and FEC indexes for each year, associated with the imposition of penalties for non-accomplishment.

conclusively to compare the resources allocated and the effort spent by each firm group in service quality provision.

To address the point, it was assumed that the different operating conditions are incorporated in the target continuity of service indexes set forth by the regulator. Ratios target over actual indexes were computed for each firm, and the resulting relative DEC and FEC measures were used to derive an equally weighted adjusted quality measure.[66] The corresponding values found for each firm group in 2003 confirmed the service quality ranking shown in Table 3-10.[67] Public firms do provide lower service quality than other firms, a finding that rules out a possible explanation for their lower efficiency level evidenced in the present study. Always private firms, on the other hand, show an adjusted quality measure that increases over the period and is well above unity in 2003, which denotes the provision of service quality at levels well above what has been required by the regulator. It is investigated below whether this "overinvestment" in quality of service might be one of the reasons for the deterioration in performance over the period experienced by these firms.

Two procedures are employed to examine the relationship between efficiency and service quality, overall and for each firm group, as well as the possible existence of economies of vertical integration. First, the *Quality* measure, interaction terms *Quality*ownership dummies*, and a vertically-integrated dummy (*Vertical*) are included as additional arguments of the variable cost function, with the resulting efficiency scores being compared to the ones obtained

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[66] The adjusted quality measure is given by: ½ $DEC_{relative}$ + ½ $FEC_{relative}$, where the relative measure equals Target (DEC or FEC) over Actual (DEC or FEC). Since service quality is inversely related to DEC and FEC values, the higher the relative measures, the higher the service quality. In addition, the higher is the computed adjusted quality measure from one, the greater is the distance from the actual service quality provided to the target defined by the regulator.

[67] The computed adjusted quality measures for year 2003 were the following: 1.566, 1.731, and 2.183, for public, privatized, and always private firms, respectively.

previously.[68] The rationale here is to consider service quality as an additional output electricity distribution companies must provide in order to accomplish the regulatory requirements. Secondly, the same variables are included as parameters of the mean inefficiency error term, in a conditional mean specification.[69]

The results obtained are reported in Table 3-11. Initially, the evidence tells that, after controlling for other factors, service quality and the fact of being vertically integrated or not do not contribute significantly to explain variations in operating costs among Brazilian electricity distribution companies (Model "A"). Both *Vertical* and *Quality* coefficients have signs contrary to what was expected and are not significant, while all other coefficients remain practically the same. Likewise, the resulting efficiency indexes are quite similar to the ones obtained previously (correlation of .9941). Note, however, that the service quality impact on operating costs differs with firms' ownership type (Model "B"). While costs increase exponentially with service quality levels for public firms, as it was expected, for privatized companies a negative relationship holds.[70] Among the privatized, the ones that provide better service quality have lower operating costs.[71]

The conditional mean specification (Models "C" and "D" in Table 3-11) reveals an unexpected positive, and marginally significant (p-value = .055), coefficient on the *Vertical*

[68] Since service quality is costly, it is expected that firms that provide better service quality are penalized when this variable is not accounted for in the analysis, by showing up as more inefficient than the ones that provide lower service quality. Hence, the control for this factor should increase efficiency indexes of firms that provide higher quality.

[69] The ownership dummies themselves were also incorporated in the specifications that included the interaction terms *Quality*ownership dummies*, to prevent attributing to service quality an effect due to the firm's ownership type.

[70] Although the coefficient on the interaction term *lnqlt*alwspr* is negative and significant, the computed elasticity of always private firms' service quality was close to zero (-.0077).

[71] In light of the longitudinal nature of the data, additional tests (random effects, between effects, and fixed effects regressions) were performed in order to ascertain that the negative relationship found between *Quality* and Opex comes from variations in *Quality* between firms.

dummy. Despite probable economies of scope, vertically integrated firms show up as more inefficient than other distribution companies. The point deserves the regulator's attention, since cost shifting is one of its possible explanatory factors.

The findings also show that quality of service provided—as it is measured in the present study—does not help explain variations in firms' efficiency levels. The coefficients on *Quality* and its squared term indicate that service quality increases inefficiency when *Quality* is higher than 1.6, a value slightly higher than the 75% percentile (1.52). Here, again, the impact differs with firms' ownership type (Model "D"). For public and always private firms the *Quality* coefficients are positive, but not significant, a result that does not confirm the raised possibility that the always private firms' "overinvestment" in quality of service was one of the reasons for their evidenced deterioration in performance. On the other hand, the findings do indicate that, among privatized companies, the more efficient ones also provide better quality of service.

At this point, it is important to note that the evidence not only supports the effectiveness of quality regulation instruments implemented by the regulator, but also suggests that the expressive privatized companies' efficiency improvement identified in the present study comes effectively from a more efficient operation of their units, in line with what was expected under an incentive regulation scheme, and not from mere reductions in costs brought by deterioration in the quality of service provided.

Conclusion

This paper confirms the theoretical predictions regarding the impact of incentive regulation on firms' performance. Brazilian electricity distribution companies have experienced high productivity growth rates after the sector reforms, above what was found in a previous study for the period before the reforms. The productivity increment relates to the closing of the efficiency gap present in 1998, and is driven by the performance of privatized and public companies.

Privatized firms responded more aggressively than public firms to the new incentives brought by price-cap regulation, denoting that incentives were higher to profit-oriented managers operating under a shareholders' pressure to quickly recoup the investments made. The study's estimate of privatized firms' incremental annual productivity growth rate (3.36%), on the other hand, brings about the need to tailor specific efficiency improvement incentives to public firms, since it represents not implemented-but-achievable productivity gains, which could have resulted in lower tariffs to customers.

The subset of firms privately owned before the reforms shows up as more efficient, on average, than other firms in the beginning of the period examined. Its productivity growth rate evidenced in the present study, therefore, is consistent with a limited space for efficiency improvements—on operating and maintenance expenses—on the more efficient firms subject to a rate of return regulation scheme. Given the sensibly higher productivity growth rates experienced by other firms, "always private" firms face a decline in their efficiency levels over the period. This research provides another possible explanation. It shows that the observed decline in these firms' mean efficiency level derives, fundamentally, from their low productivity growth in 2003, which might therefore indicate a possible strategic behavior of some of these firms, associated to the periodic aspect of the price-cap incentive regulation scheme.

The results suggest a possible occurrence of strategic behavior of another sort as well. In spite of plausible economies of scope, vertically integrated distribution companies show up as more inefficient than other firms, raising the possibility of cost shifting. Stricter rules regarding cost allocation and/or a closer look at these companies' accounting numbers may be appropriate.

Interestingly, the paper reveals that the high performance improvement experienced by privatized firms in the period does not come from mere reductions in costs brought by deterioration in the quality of service provided, a result that also indicates the effectiveness of the quality regulation instruments implemented by the regulator.

All these findings ultimately provide a better understanding of the cost opportunities faced by each firm, and consequently enable the establishment of prices conducive to a greater social welfare. The regulator has had the opportunity to define new electricity distribution prices in the periodic tariff review that started in 2003 and is still in place for some firms. On that opportunity, the choice was for the use of the model company approach to estimate each firm's efficient operational costs. This paper's findings provide the basis not only for evaluating the regulator's decisions in those circumstances, notably with respect to their consequences in terms of both distribution of productivity gains among stakeholders and incentives for further efficiency improvements, but also for examining the model company approach itself. The approach's usage is not pacific in the theory and its implementation in the Brazilian context has been disputed among the parties involved.

Table 3-1. Descriptive Statistics

Variable	1998	1999	2000	2001	2002	2003	1998-2003	Range
OPEX	98,905	85,773	84,953	74,258	70,455	70,134	80,640	[2490, 559072]
	(132857)	(111025)	(113274)	(100497)	(97838)	(97273)	(108952)	
Q	5,074,129	5,260,394	5,520,603	4,790,657	5,063,016	5,110,973	5,137,639	[103191, 37540051]
	(8442352)	(8346455)	(8719154)	(7649132)	(7569014)	(7404106)	(7970465)	
LP	38.9052	32.4873	35.9164	34.0834	39.2159	41.9181	37.1144	[6.5398, 128.4681]
	(18.9536)	(14.7348)	(18.517)	(14.7472)	(22.3052)	(21.2112)	(18.7994)	
MP	78.6138	72.8605	70.946	70.9966	68.4405	68.595	71.701	[60.008, 96.620]
	(6.7104)	(4.419)	(3.9627)	(3.5699)	(3.2352)	(3.4071)	(5.5173)	
SP	74.0168	66.802	64.4161	61.4267	53.5491	58.3822	63.022	[29.434, 98.120]
	(17.9825)	(18.4658)	(16.9462)	(14.435)	(11.4705)	(12.7854)	(16.7229)	
CUSDEN	25.7095	26.6959	27.9056	28.7718	30.8484	32.0821	28.6965	[6.747, 137.093]
	(18.6995)	(19.1257)	(20.0373)	(20.4782)	(21.8955)	(22.4005)	(20.4544)	
INDSHARE	0.2959	0.2980	0.3068	0.3132	0.3308	0.3257	0.3119	[.0333, .6438]
	(0.1461)	(0.1434)	(0.1432)	(0.1413)	(0.1498)	(0.1568)	(0.1463)	
RESDEN	2.1026	2.0789	2.0028	1.7162	1.6803	1.6774	1.8749	[.663, 4.572]
	(0.6267)	(0.6282)	(0.5139)	(0.4687)	(0.4625)	(0.4167)	(0.5537)	
AREA	129,178	129,210	129,203	131,495	126,671	126,725	128,723	[252, 1253165]
	(242029)	(239567)	(239564)	(241463)	(237902)	(237882)	(237747)	
NUMCUST	828,166	879,502	919,894	934,543	979,891	1,012,766	926,545	[19625, 5744178]
	(1099440)	(1134211)	(1188028)	(1228822)	(1255942)	(1287816)	(1193257)	
INCOME	5,769.74	5,086.45	5,160.16	4,996.71	4,386.60	4,642.68	5,001.43	[1060.012, 12747]
	(2804.22)	(2351.86)	(2379.3)	(2272.11)	(1880.11)	(1989.73)	(2317.13)	
CAP	3,218.57	3,269.12	3,269.12	3,142.07	3,206.25	3,206.25	3,218.73	[.1, 22728.4]
	(4908)	(4872.48)	(4872.48)	(4835.87)	(4751.46)	(4751.46)	(4792.04)	
LEN	41,998.10	42,957.20	42,957.20	42,959.70	42,131.10	42,131.10	42,520.10	[720.3, 379518.58]
	(65700.6)	(65399.9)	(65399.9)	(66063.9)	(64894.5)	(64894.5)	(64850.3)	
UNDERGRD	0.006592	0.006462	0.006462	0.005940	0.006338	0.006338	0.006356	[0, .1391]
	(.0246)	(.0244)	(.0244)	(.0244)	(.0241)	(.0241)	(.0241)	
# OBSERV.	50	51	51	50	52	52	306	

* Mean values reported for each year and for the period 1998-2003. Standard deviation in parentheses.

Table 3-2. Stochastic Cost Frontier Results

Variable	Time-trend formulations			Time Fixed-Effects formulations		
	A	B	C	D	E	F
ln*Opex*						
ln*Q*	0.771***	0.781***	0.803***	0.708***	0.739***	0.756***
	(.025)	(.023)	(.035)	(.018)	(.017)	(.017)
ln*LP*	0.442***	0.403***	0.409***	0.395***	0.348***	0.366***
	(.062)	(.064)	(.066)	(.034)	(.035)	(.034)
ln*MP*	0.364***	0.374***	0.315***	0.381***	0.401***	0.480***
	(.116)	(.112)	(.114)	(.068)	(.069)	(.069)
Cap	0.096***	0.108***	0.058*	0.103***	0.102***	0.080**
	(.027)	(.027)	(.034)	(.028)	(.030)	(.028)
Len	0.561***	0.561***	0.522***	0.534***	0.525***	0.516***
	(.064)	(.063)	(.064)	(.063)	(.066)	(.063)
ln*IndShare*	-0.007	0.009	-0.013	-0.008	-0.003	0.009
	(.034)	(.033)	(.035)	(.033)	(.034)	(.033)
ln*ResDen*	0.169*	0.157*	0.143	0.131	0.099	0.145*
	(.089)	(.088)	(.092)	(.089)	(.092)	(.087)
ln*Income*	-0.179***	-0.145***	-0.186***	-0.168***	-0.139***	-0.185***
	(.035)	(.037)	(.039)	(.037)	(.039)	(.040)
ln*Area*	0.072***	0.074***	0.066***	0.074***	0.073***	0.073***
	(.012)	(.011)	(.013)	(.012)	(.013)	(.012)
ln*CusDen*	0.500***	0.496***	0.466***	0.469***	0.462***	0.465***
	(.061)	(.061)	(.064)	(.062)	(0.064)	(.061)
Undergrd	4.765***	4.480***	4.486***	4.830***	4.465***	4.601***
	(.589)	(.582)	(.563)	(.602)	(.611)	(.583)
T	-0.054**	-0.052*	-0.051**			
	(.027)	(0.026)	(.025)			
ln*Q**t	-0.015***	-0.014***	-0.007			
	(.005)	(.005)	(.005)			
ln*LP**t	-0.012	-0.010	-0.014			
	(.017)	(.017)	(.017)			
ln*MP**t	0.001	0.001	0.047			
	(.029)	(.027)	(.030)			
Tsq	-0.004	-0.004	-0.005			
	(.007)	(.007)	(.007)			
Private		-0.110**				
		(.047)				
*Private**t		0.006				
		(.012)				
Privtzed			-0.094*			
			(.052)			
Alwspriv			-0.081			
			(.087)			
Privtzed*t			-0.013			
			(0.013)			
Alwspriv*t			0.029			
			(0.018)			
D1999				-0.039	0.049	-0.044
				(.033)	(.183)	(.032)
D2000				-0.106***	0.048	-0.102***
				(.033)	(.294)	(.033)
D2001				-0.150***	0.029	-0.147***
				(.034)	(.346)	(.033)
D2002				-0.268***	-0.075	-0.273***
				(.035)	(.355)	(.036)
D2003				-0.303***	-0.137	-0.308***
				(.036)	(.337)	(.035)
Cons	-0.150**	0.001	-0.142	-0.200***	-0.581	-0.437)***
	(.070)	(.052)	(.089)	(.052)	(.367)	(.105)
Mu						
Private					-0.100***	
					(.027)	
T					-0.140	
					(.269)	
Timesq					0.015	
					(.032)	
Privtzed						-0.155***
						(.032)
Alwspriv						0.022
						(.036)
Cons					0.649	0.359***
					(.577)	(.102)
lnsig2u						
Q	0.109*	0.606	-0.063	0.131**		
	(.064)	(.761)	(.102)	(.051)		
Cons	-4.423***	-15.104	-3.590***	-4.502***		
	(1.193)	(14.702)	(1.029)	(.956)		
N	306	306	306	306	306	306
Ll	128.429	136.29	144.157	120.077	124.98343	134.31818
chi2	21833.984	23964.368	17857.736	21535.49	28332.588	17974.398

Legend: * p<0.10; ** p<0.05; *** p<0.01 . Standard deviation in parenthesis. Coefficients on translog squared and interaction terms are omitted.

Table 3-3. Elasticities

	Mean	Std. Deviation	Range	At variables' median values
Output	0.7077	0.0227	[.6394 , .7530]	0.7092
Labor Price	0.3908	0.0602	[.2335 , .5319]	0.3962
Materials' Price	0.3943	0.3246	[-.2229 , 1.0662]	0.3911
Time	-0.0655	0.0300	[-.1331 , -.0058]	-0.0694

Table 3-4. Technological Change by Year and Ownership

	1998	1999	2000	2001	2002	2003	1998 - 2003	Geom. Mean
Overall	5.31%	5.75%	6.35%	6.58%	7.39%	7.83%	46.2%	6.54%
Public	5.62%	6.05%	6.66%	7.01%	7.75%	8.15%	49.0%	6.87%
Private	5.17%	5.62%	6.21%	6.37%	7.23%	7.69%	44.9%	6.38%
Privatized	7.37%	7.68%	8.36%	8.59%	9.37%	9.82%	63.4%	8.53%
Always Private	2.46%	2.89%	3.43%	3.81%	4.48%	4.96%	24.1%	3.67%

Table 3-5. Efficiency Evolution

	1998	1999	2000	2001	2002	2003
Mean Inefficiency Score	1.1279	1.1206	1.1205	1.1133	1.1134	1.1109
	(.0999)	(.0917)	(.0917)	(.0722)	(.0837)	(.0697)
Public Firms' Mean Inefficiency[1]	1.1384	1.1513	1.1499	1.1342	1.1533	1.1344
	(.1161)	(.1422)	(.1378)	(.1145)	(.1401)	(.1125)
Private Firms' Mean Inefficiency	1.1229	1.1065	1.1071	1.1034	1.0956	1.1004
	(.0928)	(.0529)	(.0583)	(.0383)	(.0272)	(.0358)
Privatized Firms' Mean Ineff.[2]	1.1516	1.1258	1.1240	1.1095	1.0962	1.0873
	(.1148)	(.0616)	(.0693)	(.0415)	(.0268)	(.0261)
"Always Private" Firms' Mean Ineff.[3]	1.0866	1.0809	1.0847	1.0958	1.0948	1.1189
	(.0285)	(.0201)	(.0281)	(.0335)	(.0287)	(.0400)
Mean Relative Inefficiency	1.0865	1.0738	1.0727	1.0645	1.0569	1.0629
	(.0963)	(.0879)	(.0878)	(.0690)	(.0794)	(.0666)
Public Firms' Mean Rel. Ineff.[1]	1.0967	1.1032	1.1008	1.0845	1.0948	1.0854
	(.1119)	(.1363)	(.1319)	(.1094)	(.1330)	(.1077)
Private Firms' Mean Rel. Ineff.	1.0818	1.0603	1.0599	1.0551	1.0400	1.0529
	(.0894)	(.0507)	(.0558)	(.0366)	(.0258)	(.0342)
Privatized Firms' Mean Rel. Ineff.[2]	1.1094	1.0788	1.0760	1.0609	1.0406	1.0403
	(.1106)	(.0591)	(.0663)	(.0397)	(.0254)	(.0249)
"Always Private" Firms' Mean Rel. Ineff.[3]	1.0467	1.0357	1.0384	1.0478	1.0393	1.0705
	(.0275)	(.0193)	(.0269)	(.0320)	(.0273)	(.0383)

Standard deviation in parenthesis.
1. Includes only the 16 firms that remained publicly owned during the whole period
2. Firms privatized from 1995 to 2003
3. Firms already private in 1995

Table 3-6. Decomposition of Privatized Firms' Efficiency Evolution

	1998	1999	2000	2001	2002	2003
Mean. Ineff. Privatized Before[1]	1.1418	1.1175	1.1244	1.1105	1.0948	1.0872
	(.1143)	(.0649)	(.0811)	(.0410)	(.0250)	(.0287)
Mean Ineff. Privatized After[2]	1.1790	1.1451	1.1229	1.1066	1.0988	1.0875
	(.1249)	(.0533)	(.0338)	(.0478)	(.0320)	(.0218)
Mean Rel. Ineff. Privatized Before[1]	1.1000	1.0708	1.0764	1.0619	1.0393	1.0402
	(.1101)	(.0622)	(.0776)	(.0392)	(.0237)	(.0275)
Mean Rel. Ineff. Privatized After[2]	1.1358	1.0973	1.0750	1.0582	1.0431	1.0405
	(.1204)	(.0511)	(.0323)	(.0457)	(.0304)	(.0209)

Standard deviation in parenthesis.
1. Firms privatized from 1995 to June/1998
2. Firms privatized from June/1998 to 2003

Table 3-7. Productivity Growth Rate and Decomposititon

	Malmquist Index	Technological Change (Frontier Shift)	Technical Efficiency Change (Catch-up)
1998 – 1999	6.04%	5.50%	0.51%
1999 – 2000	6.03%	6.05%	-0.02%
2000 – 2001	6.94%	6.42%	0.46%
2001 – 2002	6.88%	6.92%	-0.04%
2002 – 2003	7.77%	7.61%	0.11%
1998 – 2003	38.50%	37.00%	1.01%
Geometric Mean	6.73%	6.50%	0.20%

Table 3-8. Productivity Growth Rate and Decomposition by Ownership Type

		Malmquist Index	Technological Change (Frontier Shift)	Technical Efficiency Change (Catch-up)
1998 – 1999	Public	4.67%	5.83%	-1.06%
	Private	6.69%	5.35%	1.24%
	- Privatized	9.47%	7.45%	1.84%
	- Always Private	3.18%	2.68%	0.49%
1999 – 2000	Public	6.43%	6.35%	0.08%
	Private	5.84%	5.91%	-0.07%
	- Privatized	8.13%	7.97%	0.14%
	- Always Private	2.80%	3.16%	-0.35%
2000 – 2001	Public	8.11%	6.83%	1.16%
	Private	6.40%	6.23%	0.12%
	- Privatized	9.43%	8.28%	1.03%
	- Always Private	2.56%	3.62%	-1.03%
2001 – 2002	Public	5.62%	7.38%	-1.60%
	Private	7.47%	6.70%	0.70%
	- Privatized	10.03%	8.73%	1.20%
	- Always Private	4.22%	4.14%	0.07%
2002 – 2003	Public	9.45%	7.95%	1.36%
	Private	7.03%	7.46%	-0.44%
	- Privatized	10.29%	9.42%	0.80%
	- Always Private	2.45%	4.72%	-2.18%
1998 – 2003	Public	39.24%	39.38%	-0.10%
	Private	38.19%	35.90%	1.55%
	- Privatized	57.19%	49.46%	5.10%
	- Always Private	16.14%	19.70%	-2.99%
Geometric Mean	Public	6.84%	6.87%	-0.02%
	Private	6.68%	6.33%	0.31%
	- Privatized	9.47%	8.37%	1.00%
	- Always Private	3.04%	3.66%	-0.60%

Table 3-9. Productivity Growth Rate and Decomposition by Ownership Type - Firms with Q > 400,000 MWh/year

		Malmquist Index	Technological Change (Frontier Shift)	Technical Efficiency Change (Catch-up)
1998 – 1999	Overall	-2.25%	1.31%	-3.53%
	- Public	-8.29%	0.58%	-8.76%
	- Privatized	1.99%	1.26%	0.68%
	- Always Private	-3.92%	2.82%	-6.55%
1999 – 2000	Overall	10.01%	4.39%	5.38%
	- Public	9.94%	3.55%	6.15%
	- Privatized	10.87%	4.43%	6.16%
	- Always Private	7.40%	5.77%	1.52%
2000 – 2001	Overall	7.50%	7.17%	0.33%
	- Public	10.08%	6.38%	3.41%
	- Privatized	8.71%	7.27%	1.36%
	- Always Private	-0.83%	8.29%	-8.38%
2001 – 2002	Overall	7.73%	9.81%	-1.92%
	- Public	-0.58%	8.92%	-8.70%
	- Privatized	10.99%	10.06%	0.84%
	- Always Private	13.17%	10.71%	2.22%
2002 – 2003	Overall	4.84%	12.47%	-6.76%
	- Public	6.09%	11.38%	-4.69%
	- Privatized	7.36%	12.80%	-4.82%
	- Always Private	-5.85%	13.36%	-16.99%
1998 – 2003	Overall	30.56%	39.98%	-4.14%
	- Public	17.06%	34.42%	-12.84%
	- Privatized	46.48%	40.84%	3.97%
	- Always Private	9.04%	47.79%	-26.26%
Geometric Mean	Overall	5.48%	6.96%	-0.84%
	- Public	3.20%	6.09%	-2.71%
	- Privatized	7.93%	7.09%	0.78%
	- Always Private	1.75%	8.13%	-5.91%

Table 3-10. Mean Service Quality Indexes

	1999	**2000**	**2001**	**2002**	**2003**
DEC[1]	23.538	20.090	17.783	18.761	16.724
FEC[2]	23.222	21.033	18.519	18.240	15.057
Quality[3]	0.062	0.074	0.079	0.074	0.092
Quality by ownership:					
Public	0.045	0.048	0.055	0.054	0.061
Privatized	0.060	0.072	0.079	0.077	0.093
Always Private	0.082	0.106	0.106	0.090	0.125

1. Average number of days of service interruption within a year
2. Average number of interruptions within a year
3. Inverse of the average of DEC and FEC

Table 3-11. *Vertical* and *Quality* as additional regressors or as mean inefficiency parameters

Variable	A		B		C		D	
	Coeff.	Std.Dev.	Coeff.	Std.Dev.	Coeff.	Std.Dev.	Coeff.	Std.Dev.
Lnopex								
Lnq	0.708***	0.022	0.757***	0.019	0.727***	0.020	0.766***	0.018
Lnlp	0.369***	0.040	0.394***	0.039	0.369***	0.040	0.352***	0.037
lnmp	0.392***	0.073	0.449***	0.072	0.389***	0.077	0.483***	0.069
lnqxlnlp	0.037	0.035	0.026	0.031	0.016	0.035	0.030	0.030
lnqxlnmp	-0.085*	0.046	-0.144***	0.044	-0.095**	0.046	-0.126***	0.040
lnlpxlnmp	-0.182	0.138	-0.038	0.134	-0.145	0.143	0.003	0.133
lnqsq	-0.013	0.017	0.016	0.013	0.018	0.014	0.024*	0.013
lnlpsq	0.019	0.127	-0.007	0.117	0.098	0.130	0.069	0.117
lnmpsq	-0.576	0.460	-0.286	0.441	-0.535	0.477	-0.339	0.431
cap	0.072**	0.031	0.062**	0.030	0.052	0.032	0.044	0.029
len	0.581***	0.073	0.550***	0.068	0.545***	0.074	0.541***	0.070
d2000	-0.061*	0.032	-0.057**	0.029	-0.061*	0.032	-0.040	0.029
d2001	-0.096***	0.036	-0.087***	0.032	-0.101***	0.036	-0.068**	0.032
d2002	-0.203***	0.037	-0.211***	0.034	-0.210***	0.037	-0.188***	0.034
d2003	-0.238***	0.040	-0.233***	0.036	-0.253***	0.040	-0.223***	0.036
lnind	0.004	0.039	-0.008	0.036	-0.008	0.039	-0.001	0.037
lnresden	0.178	0.109	0.157	0.099	0.142	0.111	0.170	0.106
lnincome	-0.144***	0.042	-0.141***	0.043	-0.151***	0.045	-0.177***	0.043
lnarea	0.072***	0.015	0.066***	0.014	0.077***	0.015	0.072***	0.013
lncusden	0.501***	0.070	0.482***	0.064	0.467***	0.071	0.501***	0.067
undergrd	5.004***	0.636	4.370***	0.594	4.900***	0.665	4.549***	0.564
vertical	0.030	0.028	0.007	0.025				
lnqlt	-0.020	0.028	0.107***	0.040				
lnqltsq	0.027	0.024	0.058**	0.028				
privtzed			-0.155***	0.028				
alwspriv			0.012	0.040				
*lnqlt*privtz*			-0.283***	0.057				
*lnqlt*alwspr*			-0.150**	0.060				
Cons	-0.275***	0.052	-0.125***	0.041	-0.485***	0.136	-0.499***	0.047
mu								
vertical					0.049	0.031	0.056*	0.029
quality					-0.096	0.085	0.031	0.081
qltsq					0.030	0.026	-0.017	0.028
privtzed							0.064	0.065
alwspriv							-0.006	0.053
*qlt*privtz*							-0.060***	0.020
*qlt*alwspr*							0.013	0.008
Cons					0.346**	0.143	0.280***	0.063
lnsig2v								
Cons	-4.082***	0.291	-3.914***	0.088				
lnsig2u								
q	0.127**	0.055	1.553	1.700				
Cons	-4.312***	0.880	-35.512	33.250				
Statistics								
N	255		255		255		255	
ll	111.86		137.21		108.17		142.37	
chi2	18977.36		29613		23989.15		19865.29	
legend:	* p<0.10; ** p<0.05; *** p<0.01							

CHAPTER 4
THE ASSESSMENT OF FIRM'S EFFICIENCY IN PERIODIC TARIFF REVIEWS: AN EVALUATION OF THE REFERENCE UTILITY APPROACH

Introduction

One of the main tasks in the implementation of a price-cap regime resides in the establishment of cost-based prices at the scheduled tariff reviews, where the regulator faces imperfect and asymmetric information regarding firms' cost opportunities. A social welfare maximizing regulator would face pressures from customers and utility investors, leading to decisions that are more likely to balance the conflicting interests of powerful stakeholders (so rulings are likely to reflect the political economy of regulation). Price-caps provide incentives for efficiency improvements:[1] at the rate review, the regulator's intention to extract part of the firms' rents for the benefit of consumers and society has to be balanced against the objectives of promoting (1) allocative efficiency (prices that reflect minimum incremental costs), (2) financial sustainability (meeting each firm's break-even constraint), and (3) further productivity gains (through strong incentives for cost containment).

A form of yardstick regulation which has been used to tackle the cost benchmark issue consists of a bottom-up efficiency study based on the engineering knowledge of the industry process.[2] In the model company (or reference utility) approach, prices are set on the basis of the estimated costs of a hypothetical efficient firm facing the same operating conditions of the concessionary under the review process. As future prices are not linked to realized costs, the method has the merit of preserving the efficiency improvement incentives brought by the price-

[1] Under a price-cap regime, prices are fixed. The firm and its managers are the residual claimants on production cost reductions, and bear the disutility of increased managerial effort. It is thus assumed that the conditions and incentives for efficiency improvement and for the possible achievement of second best prices are settled (Joskow, 2005).

[2] The model company approach has been employed to calculate electricity distribution tariffs in Spain and some Latin-American countries, mainly Chile, Peru, Argentina, El Salvador, and Brazil (Jadresic, 2002).

cap regime.[3, 4] Other possible advantages include the control for heterogeneity in operating conditions and the fact that the regulator does not need to base its decisions on cost information provided by firms.[5]

The approach's usage, however, is not fully endorsed in the literature. Weisman (2000) asserts that the estimation of efficient costs is an untenable target, given the existing informational asymmetry between the regulated firm and the regulatory agency (or the consultants hired to perform the task), and argues that it represents a major retrogression from the price-cap approach, as the posited efficiency gains need have no foundation in actual market behavior. Gomez-Lobo and Vargas (2001), on their turn, claim that the method is excessively detailed, time-consuming, resource intensive and contributes negatively to the transparency and objectivity of the regulatory process.

It is therefore important to investigate whether the use of the model company methodology has effectively enabled the attainment of the aforementioned regulator's objectives. The evidence so far is limited. Serra (2002), and Fisher and Serra (2002) look at the experience in the telecommunications and electricity distribution sectors in Chile, and consider the findings that the method's usage led to rate of returns well above the firms' cost of capital as an indication of a persistent regulatory flaw. Grifell-Tatjé and Lovell (2001), on the other hand, examine the issue in the context of the electricity distribution in Spain and find that the engineering model was much less costly to operate than the real companies, by virtue of a smaller network and

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[3] When a price-cap plan links future prices directly to realized costs and the time between schedule reviews is relatively short, the incentives under a price-cap regime are similar to the ones under rate of return regulation (Sappington, 2002).

[4] Under a model company approach, the efficiency improvement incentives come from the fact that firms appropriate rents when their actual costs are inferior to the estimated efficient operating costs.

[5] See Galetovic and Bustos (2002), and ANEEL (2003).

lower input prices, but did not have their inputs allocated in a cost-efficient manner. The study indicates that actual companies were more cost efficient than the hypothetical efficient firms, and concludes that the engineering procedure had understated potential cost savings by nearly one-third.

The present study contributes to fill the literature gap by analyzing the results obtained with the use of the model company approach to estimate efficient operating expenditures in the Brazilian electricity distribution industry periodic tariff review. The implied performance scores are compared to those obtained using alternative methodologies—Statistical Frontier Analysis (SFA) and Data Envelopment Analysis (DEA)—under the rationale that some minor divergences might result from problems in these other methods, but greater discrepancies could reflect deficiencies in the application of the engineering approach, particularly when they are independent of the method employed for comparison.

The Brazilian case provides an exceptional opportunity to perform the investigation, as the number of distribution companies allows the use of sophisticated comparative efficiency techniques and the consequent computation of efficiency scores and analysis of their evolution over time. Thus, efficiency estimates and measures of firms' productivity improvements obtained in a previous benchmarking study portraying the distribution firms' performance in the period of six years immediately before the tariff review (Silva, 2006b) are employed to examine the results provided by the engineering approach. Particular attention is given to the degree of consistency in efficiency estimates and rankings provided by the two methods, the procedure adopted for firms which experienced the highest—and the lowest—productivity gains in the period before the review and to the possibility that the regulator's decision might have threatened the firms' financial sustainability.

In sequence, the study checks for the possible causes of the divergences found. At this point, the investigation explicitly recognizes that regulatory decisions are taken by a utility maximizing regulator that operates in a situation of asymmetric information. It is also considered that the regulator has opportunities to exercise discretion, is potentially influenced by interest groups, and is subject to direct supervision of its actions. Consequently, the analysis of regulatory outcomes addresses the possible impact of these factors, in addition to the effects of the methodology employed.

The study presents evidence that the monitoring of the regulator's activities does not lead to decisions contrary to the concessionaires' interests. In addition, the investigation shows that the aforementioned regulator's objectives at the rate review might not have been accomplished in some situations where the firms' efficiency assessments differed markedly from the ones suggested by the economic benchmarking approaches. On the one hand, the results indicate that some firms, mainly the ones serving more affluent consumers, operating in more densely populated areas and having a lower proportion of electricity delivered to industrial customers, received substantially lower repositioning indexes than the economic benchmarking methods would recommend. As a low repositioning index basically serves as a price adjustment that reduces allowed revenues, the evidence points to a possible violation of firms' break-even constraints. On the other hand, the findings reveal that significantly higher repositioning indexes might have been given to companies with the opposite characteristics: managers of firms granted higher allowed prices can see that cash flows are enhanced, even when efficiency (measured using other techniques) is not high compared with the performance of other firms. Usually, incentive systems give weaker-performing firms lower prices since there is scope for efficiency improvements. Some of the companies benefiting from ANEEL's use of the repositioning index based on engineering models do not appear in the top ten of the economic benchmarking efficiency rankings, so weaker performers seem to be rewarded.

The following section describes the methodology adopted by the regulator in the periodic tariff review and presents the resulting figures obtained. Section 3 explains the methodology and the data set employed to perform the stochastic frontier approach, presents the corresponding results, and explores their use to examine the regulator's decisions taken on the basis of the engineering approach. Section 4 describes the econometric model and presents and interprets the results. Section 5 explains the robustness check performed with the use of the DEA methodology. The final section provides concluding observations.

Institutional Background and the ANEEL Model Company Method

The power sector reforms in Brazil began in 1995. While constitutional amendments abolished the public monopoly over infrastructure industries and allowed foreign companies to bid for public concessions, the Law 8,987/95 (General Law of Concessions) set the stage for the beginning of the privatization process, represented by the auctions of Escelsa in 1995 and Light in 1996. By the end of 2000, a total of 20 distribution companies had been privatized.

In addition, part of the implementation of a new regulatory framework involved the establishment of an independent regulatory agency (ANEEL) in late 1996 and, in the same year, the commission of an international consultancy to study and propose a new model for the electricity sector. The consultant's report was released in 1997, and its proposals were incorporated into Law 9,648, issued on May of 1998.[6] One of the measures introduced by the approved model was the use of the price-cap regime to regulate distribution tariffs, replacing the previous cost-of-service system. Price-cap regulation was implemented through the signature of

[6] See Ferreira (2000), Mota (2003), and de Oliveira (2003), for detailed descriptions of the new model's characteristics.

new concession contracts, which took place from 1998 to 2000, and scheduled the first tariff review for after five (for contracts signed in 1998) or four years.[7] As a result, 61 companies were submitted to a tariff review process from April 2003 to February 2006.

The Tariff Review Methodology

Despite defining the first regulatory lag, the concession contracts were silent about the cost methodology that would be applied at the periodic review. The obligation to solve the methodological vacuum rested with the regulatory agency, which, after a long and heated discussion process,[8] established that the repositioning index for firm *i* (RI_i) would be calculated as follows:

$$RI_i = \frac{RR_i - RS_i - ER_i - OR_i}{RD_i} \qquad i = 1, \dots, n \qquad (4\text{-}1)$$

where RR_i corresponds to the revenue requirement for firm *i* in the 12-month period after the tariff review date, RS_i stands for firm *i*'s revenue from supply activities, ER_i and OR_i denote extra-concession and other revenues of firm *i* projected for the same period, respectively, and RD_i is the revenue from distribution activities that firm *i* would obtain if distribution tariffs were kept the same. The repositioning index represented the percentage increase which would be applied to firm's tariffs at the rate review. In this case, a higher revenue requirement implies a higher repositioning index and, consequently, higher prices.

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[7] Companies Escelsa and Light constituted an exception to this rule. Light was the first to have price-cap regulation applied, by order of the concession contract signed in November 1996, in which the first tariff review was scheduled to occur after seven years. Escelsa was submitted to price-cap regulation in August of 1998, and had tariff reviews every three years thereafter. Except for Escelsa, all companies had the X factor set equal to zero in the first period prior to the first full review.

[8] Peano (2005) provides a detailed description of the process implemented by the regulatory agency to define the tariff review methodology. Foster and Antmann (2004), and Byatt (2004), in turn, discuss the particularities of the deep controversy that surrounded the regulator's choice of the asset valuation methodology.

The revenue requirement was defined as the revenue needed to cover efficient operating costs and to provide an adequate return over investments prudently made, corresponding to the following:

$$RR = EC + TC + OC + ROC + DEP + T \tag{4-2}$$

where EC and TC are considered non-controllable costs and stand for the projected costs of buying energy and paying the tariff charges, respectively, OC is operating costs, ROC is the return on capital (in monetary units), DEP is depreciation, and T is the firm's taxes.

The return on capital was obtained through the application of a rate of return of 17.07% on a rate base computed under a Depreciated Optimized Replacement Cost (DORC) methodology. The operating costs allowed to be passed on to tariffs, on their turn, were given by the sum of the costs estimated for administration (ADM), commercialization (COM), and operation and maintenance (O&M) activities performed by a hypothetical efficient firm facing the same operating conditions of the concessionary under exam. The estimated rate base and efficient operating costs were, therefore, the main determinants of the authorized price increases at the rate review.

The methodology employed to come up with the operating costs figures consisted in determining, for each firm, an optimal organizational structure which would allow the concessionary to efficiently fulfill its goal of effectively delivering electricity at the required service quality levels. In order to estimate the costs associated to COM and O&M activities, all processes and activities (P&A) which the reference utility should perform were identified, along with the human and equipment resources needed to carry out each P&A. The process/activity's cost was calculated considering the respective frequency of occurrence, by valuing the required resources at market prices. Then, the final cost estimates resulted from the application of each

P&A cost to the firm's volume of capital (for O&M) and number of customers (for COM). The ADM costs, on their turn, were estimated on the basis of firms' volume of capital, number of customers, and geographical dispersion, with the identified amount of human and equipment resources required also being valued at market prices.

The tariff review process also included the definition of the X-factor for the time period for which the formula would be in effect. The analysis of the corresponding methodology employed is beyond the scope of the present study, but it is important to stress, in this respect, that the X-factor comprised the productivity gains estimated for the period up to the next tariff review (X_e), adjusted by a quality factor (X_c), with X_e being given by scale economies resulting from projected increases in output, net of investments required to meet expected increases in demand. The rationale, here, was that firms' operating costs were already adjusted to their efficient levels (with the use of the engineering approach), and no further significant technical efficiency improvements should be observed thereafter.

It is interesting, at this point, to look at the ANEEL's methodology in the context of an efficient frontier framework. In theory, the efficient operating cost provided by the engineering approach should correspond to the point in the efficient frontier associated to the firm under exam. Thus, if the approach employed effectively enabled the regulator to figure out the firms' efficiency targets, in spite of the information asymmetry, it follows that the methodology at the periodic tariff review not only determined the firms' one-time adjustment on their operating costs, but also assumed that there would not be any frontier shifts in the future. In that case, the non-adoption of a progressive path towards the efficient target raises concerns over the financial sustainability constraint of those firms which the regulator's approach revealed as the most inefficient. Note, here, that the situation gets worse if the model company resulting figure does not correspond to the firm's efficiency target, and the target is set at a level that is excessively (and unreasonably) high.

On this respect, it should be noted that the estimated efficient operating costs might not match the "true" values. As stated before, the engineering model is very detailed and provides estimates for each process/activity performed by a virtual efficient firm operating in the same conditions than the company under exam. Given the asymmetric information context, the cost parameters needed to perform the task are not only difficult to be precisely estimated (taking into account the specificities of each firm's operating conditions), but also are subject to firm's misreporting. Consequently, it is indeed possible that the parameters employed to estimate the efficient costs do not satisfactorily capture the effect of some cost drivers on firms' actual costs.[9]

Model Company Estimates

The analysis of the results provided by the engineering approach was limited by availability of data and by the decision to exclude some very small utilities, which deliver less than 100,000 MWh per year. From the 61 companies subjected to a tariff review process from April 2003 to February 2006, nine were dropped from the sample due to small size; data for three others were unavailable. Therefore, the sample includes 49 companies, responsible for 99.24% of the total electricity delivered in the country in year 2003.

The operating costs estimated for the hypothetical efficient firms are shown in Table 4-1, along with the realized operating costs reported by the concessionaries and the computed regulator's efficiency index (*ANEELEFF*), given by the ratio realized OPEX to estimated OPEX. Here, two points are worth noting: the wide range observed in the regulator's efficiency indexes

[9] This possibility was augmented in the Brazilian experience under exam, as the method and the corresponding parameters employed were used for the first time and not previously debated with the distribution companies before the beginning of the tariff review process, increasing the chance of "errors."

and the fact that, under the regulator's view, seven firms were operating more efficiently than the virtual efficient company.

The variable *ANEELEFF* varies in the range of 0.848 to 1.986, with mean 1.202. The fact that the 50% percentile is at 1.180 denotes that the distribution of regulator's efficiency indexes is skewed to the right, and the mean has been moved up by a few instances where the estimated efficient operating costs are well below realized costs. It is useful to check whether these firms identified as highly inefficient using this engineering "Model Company" methodology also show up in the worst performers grouping of SFA and DEA efficiency rankings.

Note that the engineering method resulted in the allocation of some rents to the seven companies which had repositioning indexes based on operating costs higher than their realized costs.[10] In such cases, the comparison with the results provided by the economic benchmarking approaches takes on special relevance because only the most efficient firms should be allowed to keep part of their productivity gains, as an incentive for further efficiency improvements. If these seven firms are not ranked highly by alternative methodologies, the procedure is called into question. The finding would indicate that the higher tariffs given to these firms constituted an unjustified benefit, to the detriment of customers and without regard to the efficiency improvement incentives embedded in the price-cap regime.

Comparative Efficiency Analysis

In comparative efficiency studies, a firm's efficiency is given by a measure of the distance of the observed practice to the efficient frontier, with the frontier estimation being implemented

[10] According to the repositioning index formulae (equations 4-1 and 4-2), the allowed risk-adjusted rate of return of 17.07% would be given to firms operating at the model company's efficient operating costs levels (at the "efficient frontier"). It follows that returns below 17.07% were assigned to all firms whose estimated efficient costs were below their actual costs (*ANEELEFF* >1), with the rate of return being smaller, the greater was the firm's distance to the regulator's estimated frontier (the greater *ANEELEFF* was from unity). On the other hand, returns above the 17.07% standard could be earned by the seven firms whose estimated efficient costs were higher than actual operating costs.

with either a parametric or a non-parametric technique. Non-parametric methods, like Data Envelopment Analysis (DEA), use mathematical programming techniques and neither require the specification of production or cost functions nor the imposition of behavioral assumptions. These methods are generally easy to implement, but carry an implicit restriction in the number of variables that might be used. Furthermore, they do not allow for random shocks.

Parametric methods, in turn, entail applying an *a priori* functional form to the frontier, estimated with econometric tools. They allow for hypothesis testing,[11] enabling the analyst to investigate the validity of the model specification. Tests of significance can be performed for the functional form and for the inclusion or exclusion of factors, which are of special relevance for the electricity distribution industry, where the inclusion of several factors is theoretically justifiable. Moreover, with a parametric method it is possible to allow for stochastic factors or measurement errors, which avoids the assumption that all deviations from the best practice frontier involve inefficiencies. For instance, with Stochastic Frontier Analysis (SFA) a mix of one-sided and two-sided error terms is employed, with the former capturing the firm's inefficiency and the latter capturing the effects of random variation in the operating environment.

Ideally, the decision regarding the appropriate method depends on the purposes of the study and the context under examination. In case, we are interested in investigating the evolution of efficiency from 1998 to 2003; the investigation is conducted in an environment where random shocks were present and the inclusion of several variables in the model specification, besides being theoretically justifiable, is advisable due to the great heterogeneity in operating conditions. These considerations suggest the use of a stochastic frontier approach, defined in terms of an

[11] In non-parametric models, a bootstrap technique may be used to produce confidence intervals around the estimated individual efficiency and thereby assess statistical properties of the efficiency scores generated (Simar and Wilson, 1998).

input orientation, given the output exogeneity that characterizes the electricity distribution industry.

SFA Model and Data

The SFA model employed here is detailed in Silva (2006b). It is based on an unbalanced panel of 52 companies, responsible for 99.47% of the total electricity delivered in the country in year 2003, with the data being collected for the period of 1998 to 2003. The model employs a variable cost specification, reflecting the fact that transformer capacity and network length constitute capital inputs that are fixed in the short run. Environmental variables are included as arguments of the variable cost function, instead of as mean inefficiency parameters, to control for differences in firms' operating conditions; this approach reflects the interest in having efficiency measures net of factors that impact firms' performance but are beyond the control of the concessionaries. In addition, in light of the rejection of the null hypothesis of homoskedasticity, the variance of the inefficiency error component is conditioned on a proxy of firm size, given by total electricity delivered (*Q*).

The specification adopted is then the following:

$$\begin{aligned}\ln E_{it} &= \beta_0 + \beta_y \ln y_{it} + \sum_n \beta_n \ln w_{nit} + \frac{1}{2}\beta_{yy}(\ln y_{it})^2 + \frac{1}{2}\sum_n \sum_k \beta_{nk} \ln w_{nit} \ln w_{kit} + \sum_n \beta_{yn} \ln y_{it} \ln w_{nit} \\ &+ \beta_c \ln Cap_i + \beta_l \ln Len_i + \sum_j \beta_j \ln Z_{jit} + \beta_t t + \beta_{yt} \ln y_{it} t + \sum_n \beta_{nt} \ln w_{nit} t + \frac{1}{2}\beta_{tt} t^2 + v_{it} + u_{it}\end{aligned} \tag{4-3}$$

where *E* and *y* are the cost and output measures, respectively, *w* is the vector of factor prices, *Cap* stands for transformer capacity, *Len* represents network length, *Z* is the vector of environmental variables, and it is assumed that $v_{it} \sim N(0, \sigma_v^2)$ and $u_{it} \sim N^+(0, \sigma_{uit}^2)$, with σ_{uit}^2 specified as

$$\sigma_{uit}^2 = \varphi_0 + \varphi_Q Q_{it}$$

The modeling of technical change in the way shown in equation 4-3 attempts to obtain evidence of technological change over the period considered. For the computation of firms' efficiency indexes and the consequent analysis of efficiency change, however, the study turns to the use of time-fixed effects, to control for possible changes in macroeconomic factors which might have affected firms' performance during the period under investigation. It is worth noting that the use of time-fixed effects explicitly allows the computation of efficiency indexes relative to yearly-specific frontiers.

The observed technological change (ΔTC) and technical efficiency change (ΔTE) are then combined to provide a more complete picture of the productivity improvements which occurred in the period under examination, through the computation of Malmquist productivity indices. For each firm, the Malmquist index of productivity change between two consecutive periods is given by

$$MI_j = \Delta TE_j \cdot \Delta TC_j$$

where

$$\Delta TE = -\left\{\left(\frac{Eff.Index_{j,t+1}}{Eff.Index_{j,t}}\right) - 1\right\} + 1 \qquad \text{and} \qquad \Delta TC = \left\{(1 + TC_{j,t}) \cdot (1 + TC_{j,t+1})\right\}^{1/2}$$

The dependent variable is given by the operating costs of distribution and retail service activities (*Opex*), computed as the sum of labor, materials and third party service contracts expenses, as reported in the income statement.[12,13] Electricity delivered, in MWh (Q), is the

[12] The computed labor expenses include firms' contributions to pension funds and to health insurance plans, profit sharing payments, and management wages. Some firms already report these expenses under the classification of labor expenses, but most of them do not. The necessary adjustments were made on these cases.

[13] In case of vertically integrated companies, the computation of the operating costs of distribution and retail service activities was made possible by the fact that those companies are required by law to report their expenses separated by activity.

output measure[14] and average wage, calculated as total labor expenditure divided by the number of employees, is used as a proxy for the price of labor (*LP*).[15] For the prices of materials (*MP*) and third party services (*SP*), the work uses two price indexes provided by Brazilian Institute of Statistics (IBGE), and the Caixa Economica Federal (CEF), a public financial institution that is in charge of most of the social programs of the federal government and provides financing to housing construction projects. The materials' price index reflects the observed change in the price of a basket of items used in civil construction, by state, while the third party service's index portrays the observed change in the salaries paid to an electrician, also by state. The variables *Opex*, *LP*, *MP*, and *SP* are expressed in 1998 values, being deflated by a general price index (IGP-DI).

Transformer capacity is given in MVA, and network length corresponds to the sum of high-voltage and low-voltage lines, in kilometers.[16] The environmental variables incorporated in the modeling are the following: customer density (*CusDen*), given by number of customers divided by network length; share of electricity delivered to industrial customers (*IndShare*); residential density (*ResDen*), computed as electricity delivered to residential customers divided by the number of residential customers; service area[17] (*Area*), in Km^2; ratio of underground to

[14] The use of two measures of output was prevented by the fact that electricity delivered and number of customers showed up as highly collinear, with one of them always being dropped by the statistical software employed (Stata). A better specification was provided by the former, when compared to the latter.

[15] Total labor expenditure is employed to compute average wage because it was not possible to obtain information related to number of employees segregated by sector activity, for the cases of firms that also operate on generation and transmission.

[16] Since these variables showed up as highly correlated with electricity delivered, the variables *Cap* and *Len* actually correspond to the residuals of the regression of transformer capacity on electricity delivered and network length on electricity delivered, respectively.

[17] The Brazilian case justifies the inclusion of both network length and service area in the modeling, and this is reflected in the statistical significance of both variables as either cost shifters or mean inefficiency parameters. While some companies have small service areas and relatively high network length (the ones that operate in the more densely populated states), others have high *Area* but relatively low *Len*, because they operate in states which are more sparsely populated and/or have a high share of the population not being served.

overhead lines (*Undergrd*); and income per capita, by state (*Income*), to control for variations in socio-economic conditions among states. The variables above are included among the most frequently cost driving factors employed to model electricity distribution, according to Jamasb and Pollitt (2001) in their survey of the empirical literature on comparative efficiency analysis.

The data were assembled from the regulatory agency, the companies' Web sites, the financial statements provided to the Sao Paulo Stock Exchange, the Brazilian Association of Electricity Distribution Companies (ABRADEE), IBGE, and CEF.

SFA Results and Comparison

Descriptive statistics are shown in Table 4-2. The difference between minimum and maximum values of observations collected for almost all variables employed indicates the considerable heterogeneity among firms in the sample, in terms of companies' size, system configuration, and customer structure. The evidenced disparity in firms' indicators corroborates the need to account for external factors in the comparative efficiency analysis.

Table 4-4 provides the results from the models estimated. The cost function satisfies the monotonicity condition with respect to output and factor prices at the mean, and the estimated coefficients have the expected sign, with most of them being significant. The time elasticity provides a measure of technological change. The evidence shows that there was technological progress during the sample period, with an annual rate of technological change of around 6.55%, on average, which denotes that the efficient frontier has shifted considerably from 1998 to 2003.

Firms' efficiency indexes, computed for each year in the period examined, are portrayed in Appendix B, whereas the Malmquist measures of productivity change are reported in Appendix C. The results indicate that the Brazilian electricity distribution industry's productivity increased

38.5%, on average, from 1998 to 2003.[18] The mean productivity growth rate of 6.73% stands out when it is compared to the 0.9% mean total factor productivity growth rate of the economy found by Gomes, Pessôa, and Veloso (2003) for the period of 1992 to 2000.[19] Moreover, taking the results found by Mota (2004) as a proxy for the distribution companies' average productivity gains in the period of 1994 to 1998 (around 5%),[20] it might be concluded that the sector's rate of productivity growth increased after 1998.

The comparison between the SFA and the Model Company efficiency indexes is limited to the 49 firms included in Table 4-1. Another restriction comes from the fact that in some cases the indexes to be compared do not refer to the same period, since *ANEELEFF* relates to the month/year the tariff review takes place (April/2003 to November/2005) and our SFA estimates only go up to 2003. In the analysis that follows, the SFA efficiency indexes obtained for year 2003 are used for comparison (*SFA2003*), which might introduce distortions to assessments based on reviews that occurred in late 2004 and in 2005, if the firm performs rather differently than the others in the period after December/2003.[21] The possible distortions, however, should not be relevant in the context of the present study, as the comparison of efficiency indexes focuses on the larger discrepancies in the two methods' results.

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[18] The above mentioned measure of productivity change does not incorporate the scale effect. On the basis of the computed output elasticity and the actual changes in output from year to year, we have estimated it to be equal to 3.56%, on average, from 1998 to 2003.

[19] The authors report that their result is consistent with the findings of two other studies that examined the subject.

[20] Mota obtains annual average productivity gains of about 5% in the period of 1994 to 2000 using data only from these two years and from 14 privatized companies. Considering that the present study provides evidence of significantly higher privatized firms' productivity gains for the period of 1998 to 2000, Mota's result can be taken as an upper-bound measure for average productivity gains in the period of 1994 to 1998.

[21] Similar distortions may be present for the 17 companies which experienced tariff reviews along the 2003 year. We examined the issue using for the comparison the average SFA efficiency index for years 2002 and 2003 (*SFA0203*). As expected, *SFA0203* and *SFA2003* were highly correlated ($\rho = .9674$). Moreover, the points raised in the analysis that follows were still present when the SFA0203 efficiency indexes were employed.

The efficiency rankings provided by the SFA and the engineering approaches (Table 4-5) are not significantly correlated (Spearman's ρ = 0.0682, p-value = 0.6417). The rankings show some consistency in terms of the best performers, as *Enersul*, *Coelce*, *RGE*, and *CAT-LEO* appear in both top ten extracts. Nonetheless, only *Eletropaulo* and *Jaguari* appear in both models in the bottom ten. Note, in addition, that *CEMIG* figures in the bottom ten in one method, and in the top ten in the other.

SFA efficiency estimates are significantly smaller than *ANEELEFF,*[22] varying in the 1.045 to 1.506 interval but concentrated in the 1.045 to 1.127 (75% percentile) range, with mean 1.110. It follows that the engineering approach has considered firms to be, on average, more inefficient than indicated by the SFA economic benchmarking technique. The result is not unexpected, given that one method centers on an ideal context, while the other draws upon actual practice. Moreover, as the SFA method is based on strong distributional assumptions to disentangle the effects of inefficiency and random noise, it cannot be ruled out the possibility that some inefficiency is incorrectly attributed to statistical noise.[23] In the present study, however, the comparison of efficiency indexes is restricted to the cases of higher divergence.

According to the regulator's methodology, *Eletropaulo*, *Light*, and *CEB* are considerably more inefficient than shown by the benchmarking method, as *ANEELEFF* exceeds *SFA2003* by 0.8305, 0.7604, and 0.6312, respectively. *Eletropaulo* and *Light*, however, were the two firms with the highest productivity improvements in the 1998-2003 period (Appendix C) and, according to SFA, were not distant from the average performance of other firms, which raises

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[22] The null of equality of means is rejected at the 1% significance level (p-value (H_1: ANEELEFF > SFA2003) = .0007).

[23] As suggested by the comparison to DEA efficiency measures mentioned later on Section 5, it is also possible that SFA efficiency indexes are constrained by the half-normal distribution assumed for the inefficiency error term.

serious concerns over their obligation to perform such profound further adjustments[24] and points to the existence of flaws in the application of the engineering approach.[25] One possibility is underscored by the present study. In line with Peano's (2005) claim,[26] the results suggest that the regulator's method might have been biased against firms which operate in more densely populated areas, since five firms, from the ten which had the highest positive difference between *ANEELEFF* and *SFA0203*, belong to the top ten customer density extract.

The major situations where the implementation of the model company methodology resulted in firms being considered more efficient than portrayed by SFA were the cases of *Celesc*, *Coelba*, and the seven firms which had *ANEELEFF* below one (*Energipe, Enersul, Coelce, Cemat, Cemig, Santa Maria* and *Cat-Leo*). The benefit of securing a higher rate of return over their asset base, given to these nine firms, would only be acceptable if they indeed figured in the group of best performers and had experienced high productivity improvements in the first regulatory period, since in this case the regulator would be allowing them to keep part of the efficiency gains as an incentive for further productivity increments.

Only *Cat-Leo*, *Enersul* and *Coelce*, however, show up in the SFA top ten segment. In the case of the other six firms, the SFA results indicate that the benefit given was probably unjustified and harmed customers through higher tariffs. In addition, the rulings did not provide

[24] As indicated by the Model Company efficiency index (1.986), Eletropaulo would have to further reduce its operating expenditures by almost 50% to be able to reap the allowed risk-adjusted rate of return (17.07%).

[25] Our previous study of the regulator's performance [Silva(2006a)] had already indicated that the repositioning index announced at Eletropaulo's tariff review caused a negative surprise in the market, as if it were not a conceivable number.

[26] The author compared the model company's OPEX to actual OPEX of 12 firms submitted to tariff review in year 2003, and identified that the difference between the two measures was inversely related to firm's customer density. The author argued that the model company method might have been efficient in avoiding reimbursements of over-investments in more densely populated areas, and allowed an extra return to firms with less densely populated service areas, which incur higher costs to provide the service at the required quality levels. Peano noticed, however, that the positive X-factor given at the beginning of the tariff review cycle might impact negatively the incentives for efficiency improvements.

the appropriate incentives for efficiency improvements in the following regulatory term. The *Cemig´*s case is emblematic. In spite of the considerable productivity increments in the 1998-2003 period, the firm still figured as the worst performer according to *SFA2003*. The fact that the engineering methodology shows the firm operating rather more efficiently (*ANEELEFF* – *SFA2003* = -0.5522) may derive from the company's low customer density index, but suggests the possibility of a differentiated treatment to publicly owned firms, evaluated in the next section, since *Celesc*, *Celg*, *CEEE*, and *Copel* also appear in the *SFA2003* worst performers' group but occupy considerably better positions in the Model Company ranking.

It is also worth noting that four out of the five best performers under SFA did not receive the same benefit of being able to keep part of the rents derived from accomplished productivity gains. On the contrary, the *ANEELEFF* indexes of two of them (*Manaus* and *Eletroacre*) were above 1.10, signaling that they would have to further reduce their operating costs by more than 10% to be able to earn the allowed 17.07% rate of return. This apparently tough task, however, might not be difficult to achieve, as the regulatory scheme set forth for the subsequent regulatory lag ignored the acute frontier shifts observed in the 1998-2003 period. The expected high productivity gains brought by technological change should also alleviate the economic situation of firms which might have been unduly classified as more inefficient. Unfortunately, however, they will exacerbate the perverse effects of possible over-estimating firms' efficiency.

Econometric Modeling

For each firm, the variable *ANEELvsSFA*, computed as the ratio of *ANEELEFF* to *SFA2003*, expresses the divergence in the results provided by the two methods. *ANEELvsSFA* varies in the range of 0.633 to 1.719, with mean 1.087 (see Table 4-3). The higher the variable is (relative to unity), the more the firm was considered more inefficient under the regulator's Model Company approach, when compared to the SFA standard, and the more the firm was harmed by getting a lower repositioning index (price), assuming that the SFA results are a good representation of the true values.[27] Conversely, when the firm's indicator is smaller (relative to unity), the firm was considered less inefficient under the regulator's methodology (*ANEELEFF*< *SFA2003*). In this case, the result suggests that the regulator's efficiency index was lower than it should be. Consequently, the firm, being closer to the efficient frontier than shown by the economic benchmarking method, was benefited by getting prices higher than recommended by the SFA standard.[28] A ratio of .9, for example, indicates that the firm was considered 10% closer to the efficient frontier than shown by the SFA model, or that its resulting repositioning index was augmented by .1 times the operating costs' (OC) participation on the estimated revenue requirement (see equation 4-2). Logically, the "firm's benefit" gets higher for lower values of *ANEELvsSFA*. At the lower bound ratio of 0.633, for instance, the multiplicative factor goes from the aforementioned .1 to nearly .37.

Differences in the results provided by the Model Company and economic benchmarking approaches are expected, as the engineering model does not account for substitution possibilities. Here, though, the analysis focuses on some other possible causes of the observed divergence between the two indicators. The investigation assumes the existence of a principal-agent relationship between the Congress (or the Government) and their delegated "representatives" in

[27] This assumption draws upon the soundness of the parametric model employed, which controls for heterogeneity in operating conditions, influence of macroeconomic factors, and random shocks. The rationale, therefore, is that minor differences in efficiency assessments might be due to eventual SFA inconsistencies, but bigger divergences should be accounted to problems in the application of the engineering approach. Later in Section 5, in order to ascertain the validity of this reasoning, the results' consistency is checked using performance indicators provided by an alternative methodology as the comparison parameter.

[28] The relation between the distance to the frontier and the resulting price assigned to the firm is detailed in footnote 10. Since *ANEELEFF* is given by the ratio of realized OPEX to the Model Company's estimated OPEX, it is important to stress, at this point, that when the firm shows up closer to the efficient frontier than it should be, it is because the Model Company's estimated operating costs are overestimated, according to the SFA standard. Under the same reasoning, the engineering costs would be underestimated in the reverse case where *ANEELEFF* > 1. The analysis that follows investigates the possible causes of these over- and underestimations of the Model Company's operating costs.

regulatory agencies. In this system, interest groups can influence regulatory outcomes. In addition, information asymmetries raise the possibility that the parameters employed to estimate the efficient costs do not satisfactorily capture the effect of some cost drivers on firms' actual expenditures, and affords the regulator some discretion to make choices that maximize its utility.[29]

The tariff review process presented two main opportunities for the regulator to exercise its judgment, possibly reflecting the influence of the industry and its customers: in the definition of the model company cost parameters and right after the announcement of the efficient operating cost initial estimates, when deciding upon the acceptance or rejection of firms' revision claims. Consequently, the investigation follows the line of previous empirical studies which focused on the determinants of regulatory outcomes, addressing the predictions of the economic theory of regulation associated with Stigler (1971) and Peltzman (1976) [Nelson, 1982; Primeaux, Filer, Herren, and Holas, 1984; Naughton, 1989, Nelson and Roberts, 1989; Klein and Sweeney, 1999].

The analysis, however, also accounts for the fact that the regulator's decisions were taken in the context of incomplete and imperfect information. As a result, the investigation not only examines the possibility of flaws in the engineering cost parameters employed to estimate the efficient costs, but also hypothesizes that, in the absence of the information necessary to promote

[29] This framework draws upon the contributions of Stigler (1971) and Peltzman (1976), which form the basis of the economic theory of regulation. The authors posit that stakeholders face costs of organization and information, and regulators are self-interest maximizers which allocate benefits across interest groups optimally, attempting to equate political support and opposition at the margin. The authors' contribution helps explain the location of policy in the competitive price to the monopoly price spectrum. Generally speaking, consumers, being dispersed and having less at stake, face higher costs of organization than producers and usually do not have the required incentives to spend the necessary resources to become informed. In case, the prediction is that the producer interest should win the bidding for the services of a regulatory agency. However, consumers who spend a larger share of their income on a good have a higher incentive to participate in the regulatory process and should drop more votes for the politician in response to a price rise. Therefore, goods with a high share in the consumers' budget are more likely to have prices close to the competitive price.

the desired distribution of productivity gains among stakeholders,[30] the regulator might have employed some of the available data as signals for firms' profitability and cash flow availability. In addition, the empirical analysis examines a potential external monitoring impact on the regulator's decisions.

Hence, it is hypothesized that the divergences of the regulator's efficiency measure to the SFA standard reflect two main factors: (a) possible problems in the cost parameters employed by the engineering model, due to the difficulties posed by the imperfect information context or to regulator's decisions; or (b) the regulator's adjustments in the initial operating cost estimate, made on the basis of its utility function and the available information, in a context of pressure from interest groups and direct supervision of the regulator's job.

The statistical tests are conducted through two complementary procedures: (a) an OLS regression of the divergence variable (*ANEELvsSFA*) on proxies for the explanatory factors mentioned above; and (b) an examination of the possible determinants of the regulator's adjustments in the OPEX estimate made during the rate setting, a more direct test for the influence of interest groups on the regulatory results. In this case, the investigation employs the disclosed information regarding the initial OPEX estimated via the Model Company engineering model, the firm's reported OPEX, and the final (adjusted) OPEX. These numbers are used to compute a measure of firm's bargaining power, which is then regressed on the political variables (and some other possible explanatory factors). These procedures are detailed below.

[30] The Brazilian electricity sector regulator did not employ any kind of economic benchmarking procedure to estimate the productivity increments experienced by each firm during the regulatory period before the rate review.

Specification and Data

A measure of firm's bargaining power can be expressed by the distance of the final OPEX to the corresponding initial estimate or, in other words, by the weight (W) given by the regulator to the initial OPEX estimated by the engineering model. The weight is computed as follows:

$$OPEX^{A} = W * OPEX^{E} + (1 - W)OPEX^{C}$$

$$W = \frac{OPEX^{A} - OPEX^{C}}{OPEX^{E} - OPEX^{C}}$$

where $OPEX^{A}$ stands for the final operating costs defined by the regulatory agency (ANEEL), $OPEX^{E}$ stands for the operating costs initially estimated with the application of the engineering model, and $OPEX^{C}$ is the operating costs reported by the distribution companies. These variables' values, along with the corresponding *WEIGHT* computed for each firm's tariff review, are portrayed in Table 4-1. Note that *WEIGHT* is inversely related to the bargaining effect, since the firm's bargaining power can be said to be higher when the variable gets closer to zero.

As the dependent variable is a fraction between zero and one, the estimation follows the procedure suggested by Papke and Wooldridge (1996) and employs a generalized linear model (GLM), estimated by the maximum likelihood method, assuming a binomial distribution for *W* and a logit link function. The modeling includes, as independent variables, proxies for the potential influence of interest groups, factors related to possible problems identified in the application of the engineering model, possible signals employed for firms' profitability and cash flow availability, and proxies for a potential impact caused by both the external monitoring of the regulator's activities and a likely learning effect.

These same independent variables are employed in the OLS regression. In this case, though, an additional variable is included to control for a possible problem resulting from the labor price measure used in the SFA procedure.

The explanatory variables are the following: income per capita (*INCOME*),[31] share of electricity delivered to industrial customers (*INDSHARE*), the log of total electricity delivered, in GWh (*SIZE*), customer density (*CUSDEN*), given by the log of the number of customers divided by service area, a public company dummy (*PUBLIC*), percentage growth in residential consumption per capita from 1998 to 2003 (*CONSUMPTION*), output growth in the same period (*GROWTH*), a categorical variable indicating whether or not the Tribunal de Contas da Uniao has monitored, or not, the tariff review process (*TCU*), the number of rate reviews occurring before the firm's review (*LEARNING*), and the ratio of SFA labor price to Model Company labor price (*LPDIFF*).

The variables *INCOME* and *INDSHARE* are proxies for the consumer's participation in the regulatory process. It is hypothesized that low-income residential customers should exert a higher opposition to a price increase, when compared to high-income customers. Since the income elasticity for electricity is less than one, poor families spend a greater share of their income on electricity and thus have a greater incentive to oppose high prices, assuming the time cost of political participation is proportional to income.[32] As a result, income per capita should be negatively associated to both *WEIGHT* and *ANEELvsSFA*.[33] For *INDSHARE*, however, an opposite effect is expected, since a rise in the share of electricity delivered to industrial customers should similarly lead to more opposition to high prices, as the industry has a greater stake in lobbying for lower electricity prices than residential or commercial customers. Of

[31] The state income per capita was employed for 24 companies in the sample (19 state monopolies plus five concessionaries which serve more than 90% of the consumers in the state). For the remaining 25 companies, *INCOME* corresponded to the weighted average income per capita of the ten biggest municipalities in the company's service area.

[32] Knittel (2006), however, hypothesizes that wealth per capita is positively correlated with the degree of residential interest group activity.

[33] The lower the income, the closer should be *W* to one, denoting a lower firm's bargaining power, and the lower should be the probability that *ANEELEFF* is smaller than *SFA2003*.

course, the price structure (reflecting cost allocation rules across customer categories) may be more important here than the general price level, but the two are not unrelated.

The *SIZE* variable is a proxy for the producer's lobby, under the rationale that larger companies should possess greater ability to influence regulatory decisions. Here, however, as suggested by Klein and Sweeney (1999), it is conjectured that the expected effect of firm size is indeterminate, as large utilities are more likely to receive careful scrutiny from the regulatory agency.[34]

The *CUSDEN* and *PUBLIC* variables were included in light of the points made earlier: the Model Company's results might have been biased against firms which operated in more densely populated areas, and may possibly have favored publicly owned firms. It is thus expected that *WEIGHT* and *ANEELvsSFA* increases with *CUSDEN* and decreases with *PUBLIC*.

CONSUMPTION and *GROWTH*, on their turn, represent possible signals employed by the regulator for firms' profitability and cash flow availability. The study tests the hypothesis that the regulator may have wanted to pass on to consumers some of the rents derived from economies of scale. Here, the expectation is that *GROWTH* contributes positively to both *WEIGHT* and *ANEELvsSFA*. On the other hand, the residential consumption growth (*CONSUMPTION*) captures the rationing effect. Brazil experienced an unforeseen electricity crisis in 2001, which led to an energy rationing in the period of June 2001 to February 2002.[35] The rationing measures significantly reduced the amount of electricity delivered and the average

[34] The *SIZE* variable also controls for a possible endogeneity in the TCU monitoring, detailed below, since the closer supervision of the regulator's activities during the tariff review process concentrated in the larger firms' cases.

[35] The rationing aimed at a 20% reduction in energy consumption, and was implemented through a quota system where monthly energy consumption targets were established for almost all consumers (poor residential consumers were exempted). The scheme instituted penalties for non-accomplishments and bonuses for overachievements, besides allowing the trading of quotas for nonresidential consumers. The quota system met its objectives and avoided the occurrence of blackouts. Consumption levels from June to December 2001 showed a 20% load reduction, compared to the previous year's consumption, and a 25% reduction if it is taken into account the new customers that entered the system in 2001 (Maurer, Pereira, and Rosenblat, 2005).

residential consumption, bringing financial losses to concessionaires that operate in a sector where the high fixed costs cannot be adjusted (or avoided) to compensate for the reduction in revenues. As the rationing effect differed among firms,[36] the observed change in residential consumption per capita is used as a proxy for firms' losses and included in the model to test the hypothesis that the least affected firms (the ones with higher *CONSUMPTION*) might have had relatively low price increases (higher *WEIGHT* and *ANEELvsSFA*), under the rationale that the concessionaires which had lower reductions in their cash flows had lower bargaining power in the tariff review process and, consequently, were the ones most susceptible to rent extraction to the benefit of consumers. Thus, the expectation is that *WEIGHT* and *ANEELvsSFA* vary directly with *CONSUMPTION*.

A singular feature of the Brazilian regulatory environment consists of the existence of a governmental body (Tribunal de Contas da Uniao) which supervises the regulatory agency's performance.[37] This study takes advantage of the fact that TCU closely monitored only some of the periodic tariff review processes to examine whether this external monitoring has produced an

[36] The differentiated effect among firms came mainly from the fact that the rationing measures varied among electric zones. The quota system was initially applied to the Northeast and Southeast/Center-West sub-markets only, with more stringent quotas being assigned to the former, when compared to the latter. Subsequently, the rationing was extended to part of the North region, encompassing softer rules than the ones applied previously. The rationing in that region was limited to the July to December 2001 period. The South region, in turn, was not included in the rationing. Compared to the same period of the previous year, energy consumption in the Southeast, Northeast, Center-West, North, and South sub-markets declined 31%, 28%, 25%, 10%, and 7% in the period of August to December 2001, respectively (Bardelin, 2004). As stated by Maurer, Pereira, and Rosenblat (2005, p. 72), the South, despite not being forced to ration, engaged in the load reduction effort as a result of appeals in the media and for fear of more drastic measures in the upcoming dry season.

[37] TCU is an independent organ of the state, which assists in the external control that the Congress possesses over the whole public administration. The agency audits and reviews administrative decisions of the government to ascertain that all legal procedures and rules have been followed. TCU is not a court, but the current legislation attributes to the organ the power to order the review of some procedures undertaken and to impose sanctions and penalties in cases of strong infractions to the law. TCU exercises an oversight over the regulatory agencies and has examined both the procedures and substance of regulatory decisions.

effect on regulator's decisions.[38] The intention is to shed light on the consequences of having an institution performing oversight of the regulatory agency's procedures, and possibly contribute to the literature that focuses on the optimal institutional regulatory framework. The supervision's expected effect is indeterminate, though. One might conjecture that the monitoring reduces the regulator's discretion and leads to figures closer to the ones portrayed by SFA, assuming the SFA results are good representations of the true values. In this case, however, it is not possible to anticipate the effect on the weight measure. Nonetheless, it is also possible that the external monitoring has made the regulator exercise a higher scrutiny in the monitored cases, resulting in lower bargaining power and lower estimates of efficient operational costs (higher *WEIGHT* and *ANEELvsSFA*).

The *LEARNING* variable is incorporated in the modeling to avoid attributing to firm's bargaining power (or lack of it) an effect due to "improvements" in the Model Company method's usage. This was the first time ANEEL employed the Model Company approach. It is thus reasonable to expect adjustments in the employed engineering cost parameters as more rate reviews were carried out, resulting in large changes in $OPEX^E$ at the first rate reviews, and progressively smaller changes at the reviews conducted later on. The *LEARNING* variable should then be directly related to *WEIGHT*. It is not possible, however, to anticipate the variable's effect on *ANEELvsSFA*. The continuing definition of the engineering cost parameters may either make the corresponding efficiency estimate converge to the economic benchmarking estimate, or not.

In the computation of *LPDIFF*, the Model Company labor price was given by total labor expenses estimated for the reference utility divided by the corresponding number of estimated

[38] In the specific cases it decided to closely monitor the tariff review process, TCU requested ANEEL to submit the correspondent technical notes and all other documents which supported the proposed repositioning indexes right after they were released, in order to ensure a concomitant supervision of the actions undertaken.

employees.[39] The variable is incorporated in the OLS regression only, to check whether the divergences in results provided by the two approaches are related to the fact that the SFA labor price was computed on the basis of firms' actual salaries and benefits paid, not accounting for possible inefficiencies brought by the payment of values above the market price. The higher the computed variable, the higher should be the upward bias in the firm's efficiency under SFA and, therefore, the higher should be the *ANEELvsSFA* measure.

The data were assembled from the same sources employed to perform the SFA study. Summary statistics are shown in Table 4-3. The TCU monitoring occurred in 12 out of the 49 tariff review processes examined, and 15 of the companies included in the sample are publicly owned. The average residential consumption growth of –18.3% portrays the rationing effect, whereas the computed *WEIGHT* varies in the interval of 0 to 0.998, with mean 0.641.[40]

As expected, *WEIGHT* is negatively and significantly (at the 1% level) correlated with the adjustment made in the initial OPEX estimate (ρ = -0.6371), expressed by the ratio $OPEX^A$ to $OPEX^E$ (see Table 4-1).[41] The adequacy of the variable's usage as a measure of firms' bargaining power is corroborated by its positive and significant correlation (at the 1% level) to the divergence measure *ANEELvsSFA* (ρ = 0.6324), a result that confirms the association between higher bargaining power (lower *W*) and overvaluation of firms' efficiency levels (lower *ANEELvsSFA*), and vice-versa.

[39] For each of the hypothesized reference utilities, total labor expenses were computed on the basis of market salaries especially gathered by a commissioned consultancy firm, considering the service area's specificities. In addition, the estimated figure did not include some benefits actually paid by some concessionaries (additional vacation in excess of the one-third disposed in the Constitution and profit sharing, for example).

[40] In order to be able to run the GLM model, *W* was set equal to zero in the seven cases where the computed *WEIGHT* was negative, shown in Table 4-1. In these cases, $OPEX^A$ showed up higher than $OPEX^C$ essentially by virtue of revisions implemented by the regulator after the end of the "standard tariff review procedure," under the claim of offering to firms which had reviews in the beginning of the periodic tariff review (year 2003) the same treatment (engineering cost parameters) given to firms which had reviews later on (years 2004 and 2005).

[41] The higher the adjustment, the lower is *W* and the higher is the firm's bargaining power.

The variable, however, is not free of problems. There are some cases where *W* denotes a high bargaining power in spite of a small percentage change from $OPEX^E$ to $OPEX^A$,[42] and the data provides evidence that the mentioned adjustments are related to the "improvements" in the engineering cost parameters through time, as the average percentage change on $OPEX^E$ decreased steadily as more rate reviews were carried out, from 16.5% (for the first 12 firms in the periodic tariff review process) to 1.6% (for the last 13 firms). These facts endorse the inclusion of *LEARNING* as an additional explanatory variable, and support a research strategy employing two investigation procedures; the approaches employed in the present study can be viewed as complementary ways to address a complex topic.

Results Analysis

Regression results are remarkably consistent among the GLM and OLS procedures (Table 4-6). The evidence uncovers four main explanatory factors for the methodologies' divergences in efficiency assessments. Initially, the positive and significant *LEARNING* coefficient on both GLM and OLS models suggests that the firms' order in the periodic tariff review had implications for regulatory decisions (and thus for the financial well-being of companies). The first companies that went through the rate setting experienced higher changes in their initial OPEX estimates and were benefited by the adjustments in the engineering cost parameters made through time. When *LEARNING* decreases from the variable's mean value to a value equal to the mean minus one standard deviation, the predicted *WEIGHT* decreases from 0.6902 to 0.3621 (-47.5%), and the divergence measure *ANEELvsSFA* falls 0.074 points (6.8% of the mean value). These results indicate that the earlier-reviewed firms ended up obtaining prices higher than

[42] In these cases, $OPEX^E$ was not far from $OPEX^C$. Thus, the final OPEX ($\mathrm{OPEX}^{\mathrm{A}}$), despite representing only a small percentage increase on $OPEX^E$, was very close to $OPEX^C$, leading to a small *W*. See, for example, the cases of CAT-LEO, CELB, and CFLO in Table 4-1.

recommended by the economic benchmarking method. Conversely, later-reviewed firms were considered more inefficient under the regulator's approach, compared to the SFA standard, as if the regulator had become stricter after performing more and more rate-making processes.

The results also indicate that the employed proxies for the consumers' participation in regulatory decisions are statistically significant. In both cases, however, the evidence is contrary to some interpretations of interest group theory. The *INDSHARE*'s negative coefficients indicate that firms with a higher proportion of electricity delivered to industrial customers had a higher bargaining power in the rate review (lower *W*) and were considered more efficient than shown by SFA, receiving higher prices. The estimated impact is higher for higher values of the variable.[43] Moreover, when *INDSHARE* increases from the variable's mean value to a value equal to the mean plus one standard deviation, *ANEELvsSFA* falls 0.115 points (10.6% of the mean value). The findings, in case, suggest that industrial demanders may have received higher prices than would have been approved under a SFA approach to benchmarking.

The positive coefficients on the variable *INCOME* reveal that companies which serve more wealthy customers tend to have lower bargaining power in the tariff setting and were harmed by getting lower prices, i.e., prices seem to be lower (compared to the prices that would arise under benchmarking using SFA) when customer incomes are higher. A one-standard deviation increase in *INCOME* over its mean value shifts the predicted *WEIGHT* from 0.692 to 0.8151. Additionally, a one-unit and a one-standard deviation increase in *INCOME* augments *ANEELvsSFA* by 13.2% and 0.074 points (6.8% of the mean value), respectively. The evidence, here, is consistent with the association between wealth per capita and the degree of residential

[43] As reported in Table 4-6, a one-unit increase in *INDSHARE* over its mean value decreases *W* by 7.4%.When the marginal effect is computed for a value one-standard deviation above the mean, the result indicates that a one-unit increase in *INDSHARE* decreases *W* by 8.5%.

interest group activity suggested by Knittel (2006), as if the variable were capturing the high discrepancy in the residential customers' (average) education levels across the different regions in Brazil, under the rationale that more educated customers face lower costs to become informed and participate in the tariff review process.

The anticipated impact of customer density on the regulator's results is confirmed as well. The results indicate that the more densely populated the service area, the lower the company's bargaining power (here the coefficient estimate is only marginally significant) and the more harmed was the firm by receiving a repositioning index lower than the SFA benchmarking procedure would recommend. On the other hand, companies operating in less densely populated areas were considered more efficient than shown by the SFA method and, consequently, benefited from higher prices. The estimated impact is nontrivial, as the *CUSDEN*'s change from the variable's mean value to a value equal to the mean plus or minus one standard deviation shifts the *ANEELvsSFA* measure by 0.122 points, roughly 11.2% of its mean. This finding corroborates Peano's (2005) claim that the regulator may have wanted to provide an extra return to firms serving less densely populated service areas. However, the result might also indicate a technical problem in the definition of the cost parameters employed in the engineering model, which overstated the costs incurred by firms operating under this condition.

Some other results should be highlighted. The aforementioned potential problem associated to the SFA labor price variable is not confirmed and neither is the conjectured favorable treatment given to publicly owned firms. In addition, although the regulator knew in advance which reviews would be closely monitored,[44] the results indicate that supervision did not affect the types of decisions in a systematic way, suggesting that ANEEL was consistent,

[44] See footnote 38.

regardless of specific oversight. In particular, the evidence does not support the hypothesis that the external monitoring may have made the regulatory agency be more strict in its analysis, to the detriment of the distribution companies. This finding is important, as it corroborates the view that the TCU's supervision of the regulator's activities does not increase firms' regulatory risk. Finally, the positive and marginally significant coefficient found for the *SIZE* variable, in both GLM and OLS models, does not support the conjectured producer's influence on regulatory decisions, as it points to larger firms receiving prices lower than would have been approved under a SFA benchmarking. Here, the evidence suggests that large utilities possibly received greater scrutiny from the regulatory agency.

Robustness Check: DEA

Since the discussion above rests on the assumption that SFA estimates are good representations of the true efficiency measures, the results' robustness is checked by performing the analysis with the use of efficiency estimates provided by an alternative benchmarking procedure. In case, the same dataset is employed to investigate firms' efficiency levels and their evolution over time using a DEA technique. Here, the main concern was to use a specification which could control for exogenous features of the operating environment and be comparable to the previous parametric modeling. The option was for the use of the approach proposed by Fried, Schmidt, and Yaisawarng (1999), based on a four-stage procedure to obtain measures of managerial inefficiency separated from the influence of external operating conditions.

The first stage involves the calculation of an input-oriented DEA frontier under variable returns to scale (VRS), using electricity delivered (*Q*) as the output, and *Opex*, *Cap*, and *Len* as inputs. Specific DEA frontiers are computed for each year in the sample. Therefore, the procedure provides measures of the relative efficiency of each firm in each period by reference to yearly-specific frontiers, as well as information on input slacks and output surpluses of each observation. The efficiency scores obtained at this stage, however, do not account for differences in the operating environment across production units.

In a second stage, total input slacks are computed as the sum of radial plus non-radial input slacks of each observation, and expressed as percentages of input quantities, as total slacks may depend upon external environment as well as unit size.[45] The resulting total input slacks measures are then regressed on the six environmental variables previously mentioned (*CusDen, IndShare, ResDen, Area, Undergrd,* and *Income*), with the purpose of identifying the effect of external conditions on the excessive use of inputs. Given that input slacks are censored at zero by definition, three tobit regressions (one for each input) are estimated separately. More formally:

$$TIS_j^k = f_j(Q_j^k, \beta_j, u_j^k), \qquad j = 1, \dots, N; \qquad k = 1, \dots, K$$

where TIS_j^k is unit *k*'s total radial plus non-radial slack for input *j* based on the DEA results from stage 1, expressed as a percentage of actual input *j* quantity, Q_j^k is the vector of variables characterizing the operating environment for unit *k* that may affect the utilization of input *j* , β_j is a vector of coefficients, and u_j^k is a disturbance term.

In a third stage, the regressions' estimated coefficients are used to predict total input slack for each input and for each unit based on its external variables. The predicted values represent the "allowable" slack, due to the operating environment.

$$\hat{TIS}_j^k = f_j(Q_j^k, \hat{\beta}_j) \qquad j = 1, \dots, N; \qquad k = 1, \dots, K$$

[45] The definition of the total input slack measure in terms of percentage of actual input quantities is recommended by Fried et al. (1999, note 19) for the situation where the firm size differs significantly among firms in the sample.

These predictions, in turn, are employed to adjust the primary input data for each unity according to the difference between maximum predicted slack and predicted slack, under the rationale of establishing a base equal to the least favorable set of external conditions.[46]

$$x_j^{k_{adj}} = x_j^k * \left[1 + \left(Max^k \left\{\hat{TIS}_j^k\right\} - \hat{TIS}_j^k\right)\right]$$

In the final stage, the adjusted input variables are employed to re-run the initial input-oriented DEA VRS model, and generate efficiency scores for each firm in each period net of factors out of management control (Appendix B). In line with the procedure adopted before, the DEA efficiency measures obtained for year 2003 (*DEA2003*) are used for comparison to the SFA and Model Company results.

DEA efficiency estimates are significantly higher than *SFA2003*,[47] varying in the range of 1 to 2.38, with mean 1.28. This fact, taken together with the evidenced similarity between *DEA2003* and *ANEELEFF* distributions,[48] suggests that either some inefficiency is attributed to statistical noise in the SFA approach, or the SFA efficiency indexes are constrained by the half-normal distribution assumed for the inefficiency error term. On the other hand, even though *DEA2003* and *SFA2003* efficiency measures and rankings are not significantly correlated,[49] there

[46] With this procedure, a firm with external variables corresponding to this base level would not have its input vector adjusted at all, and a firm with external variables generating a lower level of predicted slack would have its input vector adjusted upward to put in on the same basis as the firm with the least favorable external environment. In other words, predicted slack below the maximum predicted slack is attributable to external conditions more favorable than the least favorable conditions prevailing in the sample for that input. By increasing the input vector and leaving the output vector unchanged, the firm's performance is purged of the external advantage (Fried et al., 1999).

[47] The null of equality of means is rejected at the 1% significance level (p-value (H_1: *DEA2003* > *SFA2003*) = .0001). When the equality of *DEA2003* and *ANEELEFF* means is tested, however, the null is not rejected.

[48] Data on the respective mean and standard deviation are provided in Table 4-5. The difference in means is not statistically significant, as mentioned in the previous note, but *DEA2003's* distribution of efficiency indexes is slightly more spread out than *ANEELEFF's*.

[49] The correlation statistic and the Spearman's rank correlation amount to -0.0579 (p=.6927) and -0.0751 (p=.5966), respectively.

is some consistency in terms of best and worst performers. Five firms appear in both top ten extracts, and four firms in both bottom ten (Table 4-5).

The comparison between *DEA2003* and *ANEELEFF* corroborates the indication that the Model Company approach understated some firms' efficiency levels. Similarly to what was found in the comparison to *SFA2003*, *ANEELEFF* of firms *Eletropaulo*, *Light*, *CEB*, *Eletroacre*, *Eletrocar, Piratininga*, *Boavista*, and *CPFL* are considerably higher than *DEA2003* in absolute terms. Additionally, some of the previously mentioned cases of overevaluations of firms' efficiency are confirmed as well, as the model company efficiency indexes of firms *Enersul*, *Energipe*, *Cemig*, *Coelce*, *Celesc*, *Coelba*, and *Cat-Leo* are well below both *SFA2003* and *DEA2003*. On this respect, the DEA findings provide additional support to the indication that the benefit given to *Energipe*, *Celesc*, and *Coelba* was unjustified, since these firms do not belong to the DEA top ten segment either.

The robustness check employs the same OLS model described in the previous section, with the difference that the dependent variable is now given by a new divergence measure (*ANEELvsDEA*), computed as the ratio of *ANEELEFF* to *DEA2003*. *ANEELvsDEA* varies in the range of 0.459 to 1.986, with mean 0.986 (Table 4-3), and is significantly (1% level) correlated with the preceding divergence measure ($\rho = 0.7743$). As reported in Table 4-6, the fitted model is not as well specified as before (smaller R^2), but the Wald specification test still rejects the null that the coefficient estimates are all equal zero (p-value = 0.0006). The results confirm the previously noted effects of *Industrial Share*, *Income*, and *Customer Density* variables. The findings, however, do not support the *Learning* effect identified before, or the possible impact of the *Size* variable.

Concluding Observations

The present study examines the application of the Model Company approach in the Brazilian electricity distribution sector periodic tariff reviews (April/2003 to February/2006). The resulting firms' efficiency measures are evaluated with the use of efficiency estimates obtained from both a parametric and a non-parametric benchmarking model and indices of productivity changes experienced in the six-year period before the rate review. In the process, the study tests for possible causes of the identified divergences in efficiency assessments and checks for potential determinants of firms' bargaining power in the rate setting process.

Despite the criticisms made to its subjectivity and complexity, the Model Company approach has become increasingly popular for the determination of electricity distribution tariffs in Latin America (Jadresic, 2002). It is therefore important to verify whether the methodology has both provided an opportunity for firms to meet their break-even constraints and enabled the attainment of a welfare maximizing regulator's rate setting objectives: extracting part of the firms' rents for the benefit of consumers and society, achieving allocative efficiency, and offering incentives for further productivity improvements.

However, regulatory decisions are made by a regulator operating under information asymmetries, facing the influence of interest groups and, in the specific case examined here, subject to direct supervision of its actions. Thus, the analysis of regulatory outcomes addresses the possible impact of these factors, in addition to the effects of the methodology employed.

The investigation reveals that the regulator's objectives might not have been welfare maximizing in some situations. On the one hand, some firms were considered to be rather more inefficient than shown by both SFA and DEA models, resulting in substantially lower price increases: this result raises concerns over the companies' long-term financial sustainability. On the other hand, the results point to the existence of firms which the regulator's method considered to be much more efficient than suggested by the two widely-used benchmarking methodologies.

The study provides new findings on possible causes for these divergences in the context of a particular regulatory system. The results indicate that firms with a lower proportion of electricity delivered to industrial customers, which serve wealthier consumers and operate in more densely populated areas, had lower bargaining power in the tariff setting and were harmed by getting prices lower than recommended by the economic benchmarking methods. These results are consistent with the economic theory of regulation which posits that political influence affects the level of prices. On the other hand, firms with opposite characteristics had higher bargaining power and benefited from higher prices. The evidence is consistent with an association between per capita income and the effectiveness of residential interest group activity. Moreover, the findings point to a possible inaccuracy of the cost parameters employed in the engineering Model Company approach; the parameters may inaccurately capture the effect of consumers' dispersion (customer density) on firms' operating costs, due to either the technical difficulty in defining the "true" parameter in a context of imperfect and asymmetric information, or a deliberate intention to avoid compensating investors in utilities operating in areas of higher consumer concentration, and to provide extra returns to firms working in less densely populated areas (Peano, 2005).

This benefit given at the beginning of the tariff review cycle impacted negatively the incentives for efficiency improvements provided to firms which do not appear in the top ten segments of SFA and DEA efficiency ranking. The same disincentive was received by four of the top five firms in the SFA ranking, which could not keep part of the rents brought by their productivity improvements. In sum, the regulator's methodology imposed on firms a one-time adjustment to the virtual company's efficient operating costs, which in some cases were rather different than the ones estimated by the benchmarking methods. Moreover, the rulings (and associated price trajectories) ignored the significant frontier shifts of almost 7% per year revealed by the parametric modeling, a point that would exacerbate the perverse effects of the hypothesized over-evaluations of firms' efficiency.

Interestingly, the findings do not provide support to the hypothesis that the monitoring of the regulator's activities may lead to decisions contrary to firms' interests and increase firms' regulatory risk, one of the possible effects of having an institution supervise the regulator's job. Regulator's decisions were not affected in a systematic way by special oversight. Despite its specificity, the result adds to the literature on the optimal regulatory framework design.

It should be stressed that the results outlined above are robust to the choice of benchmarking methodology (SFA or DEA) to employ as a comparison parameter. Moreover, the results do not support those who are concerned with possible limitations of the SFA methodology. However, for those who are more hesitant to abandon engineering models, at a minimum the present investigation presents a way to promote greater transparency to the process and credibility for the results obtained with the application of the Model Company method. Once the divergences in efficiency assessments are identified, and possible explanatory factors are uncovered, it remains the regulator's job to justify the choices made or demonstrate that the divergences do not come from deficiencies in the application of a particular methodology.

The proposed joint use of a comparative efficiency analysis technique benefits all stakeholders including the regulator; the agency could employ other benchmark techniques to alleviate potential adverse selection problems and consequently come up with more reliable approximations of firms' break-even points. It would then be possible to better exploit the price-cap incentives for efficiency improvements[50] and promote the desired allocation of productivity gains among stakeholders. Note, on this topic, that the redistribution of rents should ideally be based on information regarding the productivity increments of each firm during the whole regulatory period prior to the next review, information that the model company approach alone cannot provide.

The experience so far on setting price caps has indicated that quantitative benchmarking techniques may at least serve as an additional tool to the regulator, whose importance is underscored by information contained in comparisons available from having a large number of companies in the regulated industry.[51] Thus, there appears to be no reason for not using them in the Brazilian electricity distribution industry.

[50] The efficiency improvement incentives associated to the price-cap method are often hindered by the regulator's uncertainties about firms' inherent costs, which usually lead to tariffs set at a too high level, given the fear of violating firms' financial sustainability constraint. Comparative efficiency analysis helps reduce the regulator's informational disadvantage and enables the definition of better participation constraints, thereby allowing a more fruitful use of high-powered incentive mechanisms.

[51] The use of benchmarking techniques on regulatory price reviews is discussed by Rossi and Ruzzier (2000), Pollitt (2005), Stern (2005), and Dassler, Parker, and Saal (2006), among others.

Table 4-1. Initially Estimated OPEX, Final OPEX, and Firm's Reported OPEX

COMPANY	$OPEX_E$ (A)	$OPEX_A$ (B)	$OPEX_C$ (C)	ANEELEFF[1]	WEIGHT[2]	ORDER[3]	(B) / (A)	(A) / (C)
AES-SUL	152,378,578	168,526,897	213,700,000	1.2680	0.7367	2	10.60%	71.30%
BANDEIRANTE	178,748,147	200,857,495	254,995,034	1.2695	0.7100	6	12.37%	70.10%
BOA VISTA	19,299,948	19,312,706	26,152,813	1.3542	0.9981	24	0.07%	73.80%
BRAGANTINA	22,762,688	27,599,813	35,211,066	1.2758	0.6114	9	21.25%	64.65%
CAIUÁ	34,405,902	39,736,410	48,111,601	1.2108	0.6111	9	15.49%	71.51%
CAT-LEO	69,812,982	73,173,281	73,047,000	0.9983	-0.0390	12	4.81%	95.57%
CEAL	145,326,676	146,266,520	175,019,103	1.1966	0.9683	22	0.65%	83.03%
CEB	127,222,668	145,601,583	257,359,512	1.7676	0.8588	16	14.45%	49.43%
CEEE	231,085,795	235,718,790	266,328,472	1.1299	0.8685	17	2.00%	86.77%
CELB	26,293,985	27,302,875	29,812,883	1.0919	0.7133	19	3.84%	88.20%
CELESC	411,731,525	440,713,597	520,128,813	1.1802	0.7326	15	7.04%	79.16%
CELG	455,583,137	483,121,893	580,123,409	1.2008	0.7789	23	6.04%	78.53%
CELPA	229,717,734	269,031,550	310,500,443	1.1541	0.5133	5	17.11%	73.98%
CELPE	374,778,267	379,210,684	476,485,325	1.2565	0.9564	20	1.18%	78.65%
CELTINS	74,420,106	82,065,329	94,330,458	1.1495	0.6160	14	10.27%	78.89%
CEMAR	212,939,949	217,204,197	258,866,541	1.1918	0.9072	22	2.00%	82.26%
CEMAT	172,964,954	197,274,615	187,200,000	0.9489	-0.7077	1	14.05%	92.40%
CEMIG	808,746,752	936,572,499	893,609,000	0.9541	-0.5063	1	15.81%	90.50%
CENF	19,073,913	19,748,356	22,158,000	1.1220	0.7813	12	3.54%	86.08%
CEPISA	140,241,902	141,016,014	160,151,652	1.1357	0.9611	22	0.55%	87.57%
CERJ	278,164,419	297,502,578	391,983,902	1.3176	0.8301	8	6.95%	70.96%
CERON	122,533,378	122,743,263	130,521,640	1.0634	0.9737	25	0.17%	93.88%
CFLO	10,983,263	11,658,505	12,462,079	1.0689	0.5434	9	6.15%	88.13%
COELBA	341,063,413	431,347,472	437,000,000	1.0131	0.0589	3	26.47%	78.05%
COELCE	244,517,894	282,727,424	260,000,000	0.9196	-1.4680	3	15.63%	94.05%
COPEL	588,545,532	606,611,885	688,548,640	1.1351	0.8193	13	3.07%	85.48%
COSERN	97,792,392	113,400,305	136,100,000	1.2002	0.5926	3	15.96%	71.85%
CPFL	328,589,815	421,760,792	549,100,000	1.3019	0.5775	1	28.35%	59.84%
ELEKTRO	323,531,823	348,509,294	436,873,603	1.2535	0.7796	5	7.72%	74.06%
ELETROPAULO	588,395,853	645,184,235	1,281,200,000	1.9858	0.9180	4	9.65%	45.93%
MANAUS	87,650,951	87,948,585	102,481,654	1.1652	0.9799	24	0.34%	85.53%
ENERGIPE	68,983,023	82,571,280	70,000,000	0.8478	-12.3614	3	19.70%	98.55%
ENERSUL	112,343,069	130,154,623	113,300,000	0.8705	-17.6132	1	15.85%	99.16%
ESCELSA	209,658,844	217,182,804	275,672,979	1.2693	0.8860	15	3.59%	76.05%
LIGHT	463,351,823	516,334,111	944,760,674	1.8297	0.8899	7	11.43%	49.04%
NACIONAL	19,052,515	22,337,700	29,134,454	1.3043	0.6742	9	17.24%	65.40%
PIRATININGA	170,825,329	191,017,669	265,380,252	1.3893	0.7864	6	11.82%	64.37%
RGE	157,117,648	170,367,818	174,089,900	1.0218	0.2193	2	8.43%	90.25%
SAELPA	185,395,425	190,428,585	214,242,000	1.1251	0.8255	22	2.71%	86.54%
SANTA CRUZ	40,012,199	44,081,288	48,887,827	1.1090	0.5415	9	10.17%	81.84%
SANTA MARIA	16,498,783	19,771,653	19,299,425	0.9761	-0.1686	10	19.84%	85.49%
V. PARANAP.	31,929,120	37,622,908	45,725,014	1.2154	0.5873	9	17.83%	69.83%
CSPE	17,823,015	19,150,347	23,078,303	1.2051	0.7474	9	7.45%	77.23%
DMEPC	16,750,348	17,466,270	19,635,723	1.1242	0.7519	13	4.27%	85.31%
ELETROACRE	31,603,551	32,045,408	35,519,561	1.1084	0.8872	25	1.40%	88.98%
ELETROCAR	11,932,292	11,958,308	16,844,993	1.4086	0.9947	21	0.22%	70.84%
JAGUARI	10,677,128	11,157,355	15,783,997	1.4147	0.9060	9	4.50%	67.65%
MOCOCA	12,246,733	13,167,147	16,895,193	1.2831	0.8020	9	7.52%	72.49%
XANXERÊ	10,165,730	11,223,622	12,416,298	1.1063	0.5299	15	10.41%	10.41%

1. Regulator's Efficiency Index: ratio $OPEX^C$ over $OPEX^A$

2. The Weight shows how close the Final OPEX ($OPEX^A$) is to the Engineering Estimated OPEX ($OPEX^E$).

3. Firm's order in the tariff review process.

Table 4-2. SFA Descriptive Statistics

Variable	1998	1999	2000	2001	2002	2003	1998-2003	Range
OPEX	98,905	85,773	84,953	74,258	70,455	70,134	80,640	[2490, 559072]
	(132857)	(111025)	(113274)	(100497)	(97838)	(97273)	(108952)	
Q	5,074,129	5,260,394	5,520,603	4,790,657	5,063,016	5,110,973	5,137,639	[103191, 37540051]
	(8442352)	(8346455)	(8719154)	(7649132)	(7569014)	(7404106)	(7970465)	
LP	38.9052	32.4873	35.9164	34.0834	39.2159	41.9181	37.1144	[6.5398, 128.4681]
	(18.9536)	(14.7348)	(18.517)	(14.7472)	(22.3052)	(21.2112)	(18.7994)	
MP	78.6138	72.8605	70.946	70.9966	68.4405	68.595	71.701	[60.008, 96.620]
	(6.7104)	(4.419)	(3.9627)	(3.5699)	(3.2352)	(3.4071)	(5.5173)	
SP	74.0168	66.802	64.4161	61.4267	53.5491	58.3822	63.022	[29.434, 98.120]
	(17.9825)	(18.4658)	(16.9462)	(14.435)	(11.4705)	(12.7854)	(16.7229)	
CUSDEN	25.7095	26.6959	27.9056	28.7718	30.8484	32.0821	28.6965	[6.747, 137.093]
	(18.6995)	(19.1257)	(20.0373)	(20.4782)	(21.8955)	(22.4005)	(20.4544)	
INDSHARE	0.2959	0.2980	0.3068	0.3132	0.3308	0.3257	0.3119	[.0333, .6438]
	(0.1461)	(0.1434)	(0.1432)	(0.1413)	(0.1498)	(0.1568)	(0.1463)	
RESDEN	2.1026	2.0789	2.0028	1.7162	1.6803	1.6774	1.8749	[.663, 4.572]
	(0.6267)	(0.6282)	(0.5139)	(0.4687)	(0.4625)	(0.4167)	(0.5537)	
AREA	129,178	129,210	129,203	131,495	126,671	126,725	128,723	[252, 1253165]
	(242029)	(239567)	(239564)	(241463)	(237902)	(237882)	(237747)	
NUMCUST	828,166	879,502	919,894	934,543	979,891	1,012,766	926,545	[19625, 5744178]
	(1099440)	(1134211)	(1188028)	(1228822)	(1255942)	(1287816)	(1193257)	
INCOME	5,769.74	5,086.45	5,160.16	4,996.71	4,386.60	4,642.68	5,001.43	[1060.012, 12747]
	(2804.22)	(2351.86)	(2379.3)	(2272.11)	(1880.11)	(1989.73)	(2317.13)	
CAP	3,218.57	3,269.12	3,269.12	3,142.07	3,206.25	3,206.25	3,218.73	[.1, 22728.4]
	(4908)	(4872.48)	(4872.48)	(4835.87)	(4751.46)	(4751.46)	(4792.04)	
LEN	41,998.10	42,957.20	42,957.20	42,959.70	42,131.10	42,131.10	42,520.10	[720.3, 379518.58]
	(65700.6)	(65399.9)	(65399.9)	(66063.9)	(64894.5)	(64894.5)	(64850.3)	
UNDERGRD	0.006592	0.006462	0.006462	0.005940	0.006338	0.006338	0.006356	[0, .1391]
	(.0246)	(.0244)	(.0244)	(.0244)	(.0241)	(.0241)	(.0241)	
# OBSERV.	50	51	51	50	52	52	306	

Mean values reported for each year and for the period 1998-2003. Standard deviation in parentheses.

Table 4-3. GLM and OLS Descriptive Statistics

Continuous Variables	*Mean*	*Std. Deviation*	*Range*	*Categorical Variables*	*Value*	*Frequency*
WEIGHT	0.641	0.323	(0, 0.998)	*PUBLIC*	0	34
ANEELVSSFA	1.087	0.202	(0.633, 1.719)		1	15
ANEELVSDEA	0.986	0.298	(0.459, 1.986)	*TCU*	0	37
CUSDEN(LN)	2.825	1.511	(0.250, 7.019)		1	12
LPDIFF	0.978	0.414	(0.301, 2.474)			
INCOME (LN)	2.065	0.558	(0.856, 3.795)			
INDSHARE	0.322	0.158	(0.039, 0.644)			
SIZE (LN)	0.702	1.567	(-2.083, 3.491)			
CONSUMPTION	-18.297	10.474	(-65.217, 6.820)			
GROWTH	12.194	13.607	(-22.525, 37.771)			
LEARNING	22.694	14.585	(0, 47)			

Table 4-4. Stochastic Cost Frontier Results

Variable	Time-trend formulations			Time Fixed-Effects formulations		
	A	B	C	D	E	F
Ln*Opex*						
Ln*Q*	0.771***	0.781***	0.803***	0.708***	0.739***	0.756***
	(.025)	(.023)	(.035)	(.018)	(.017)	(.017)
Ln*LP*	0.442***	0.403***	0.409***	0.395***	0.348***	0.366***
	(.062)	(.064)	(.066)	(.034)	(.035)	(.034)
ln*MP*	0.364***	0.374***	0.315***	0.381***	0.401***	0.480***
	(.116)	(.112)	(.114)	(.068)	(.069)	(.069)
Cap	0.096***	0.108***	0.058*	0.103***	0.102***	0.080**
	(.027)	(.027)	(.034)	(.028)	(.030)	(.028)
Len	0.561***	0.561***	0.522***	0.534***	0.525***	0.516***
	(.064)	(.063)	(.064)	(.063)	(.066)	(.063)
ln*IndShare*	-0.007	0.009	-0.013	-0.008	-0.003	0.009
	(.034)	(.033)	(.035)	(.033)	(.034)	(.033)
ln*ResDen*	0.169*	0.157*	0.143	0.131	0.099	0.145*
	(.089)	(.088)	(.092)	(.089)	(.092)	(.087)
ln*Income*	-0.179***	-0.145***	-0.186***	-0.168***	-0.139***	-0.185***
	(.035)	(.037)	(.039)	(.037)	(.039)	(.040)
ln*Area*	0.072***	0.074***	0.066***	0.074***	0.073***	0.073***
	(.012)	(.011)	(.013)	(.012)	(.013)	(.012)
ln*CusDen*	0.500***	0.496***	0.466***	0.469***	0.462***	0.465***
	(.061)	(.061)	(.064)	(.062)	(0.064)	(.061)
Undergrd	4.765***	4.480***	4.486***	4.830***	4.465***	4.601***
	(.589)	(.582)	(.563)	(.602)	(.611)	(.583)
T	-0.054**	-0.052*	-0.051**			
	(.027)	(0.026)	(.025)			
ln*Q**t	-0.015***	-0.014***	-0.007			
	(.005)	(.005)	(.005)			
ln*LP**t	-0.012	-0.010	-0.014			
	(.017)	(.017)	(.017)			
ln*MP**t	0.001	0.001	0.047			
	(.029)	(.027)	(.030)			
Tsq	-0.004	-0.004	-0.005			
	(.007)	(.007)	(.007)			
Private		-0.110**				
		(.047)				
*Private**t		0.006				
		(.012)				
Privtzed			-0.094*			
			(.052)			
Alwspriv			-0.081			
			(.087)			
D1999				-0.039	0.049	-0.044
				(.033)	(.183)	(.032)
D2000				-0.106***	0.048	-0.102***
				(.033)	(.294)	(.033)
D2001				-0.150***	0.029	-0.147***
				(.034)	(.346)	(.033)
D2002				-0.268***	-0.075	-0.273***
				(.035)	(.355)	(.036)
D2003				-0.303***	-0.137	-0.308***
				(.036)	(.337)	(.035)
Cons	-0.150**	0.001	-0.142	-0.200***	-0.581	-0.437)***
	(.070)	(.052)	(.089)	(.052)	(.367)	(.105)
lnsig2v						
Cons	-3.964***	-3.734***	-4.242***	-3.898***		
	(.307)	(.080)	(.486)	(.242)		
lnsig2u						
Q	0.109*	0.606	-0.063	0.131**		
	(.064)	(.761)	(.102)	(.051)		
Cons	-4.423***	-15.104	-3.590***	-4.502***		
	(1.193)	(14.702)	(1.029)	(.956)		
Statistics						
N	306	306	306	306	306	306
Ll	128.429	136.29	144.157	120.077	124.98343	134.31818
Chi2	21833.984	23964.368	17857.736	21535.49	28332.588	17974.398

Legend: * p<0.10; ** p<0.05; *** p<0.01 . Standard deviation in parenthesis. Coefficients on translog squared and interaction terms are omitted.

Table 4-5. Efficiency Rankings and Indexes

Ranking	*ANEELEFF*		*SFA2003*		*DEA2003*	
	Company	Eff. Index	Company	Eff. Index	Company	Eff. Index
1	ENERGIPE	0.848	RGE	1.045	AES-SUL	1.000
2	ENERSUL	0.871	CAT-LEO	1.057	CEMIG	1.000
3	COELCE	0.920	CELB	1.059	COELCE	1.000
4	CEMAT	0.949	ELETROACRE	1.060	CPFL	1.000
5	CEMIG	0.954	ELN/AM (MANAUS)	1.062	ELETROPAULO	1.000
6	SANTA MARIA	0.976	ENERSUL	1.065	ELN/AM (MANAUS)	1.000
7	CAT-LEO	0.998	COELCE	1.068	LIGHT	1.000
8	COELBA	1.013	COSERN	1.069	PIRATININGA	1.000
9	RGE	1.022	LIGHT	1.069	RGE	1.000
10	CERON	1.063	CEAL	1.070	ELETROACRE	1.000
11	CFLO	1.069	CEMAR	1.072	ELETROCAR	1.000
12	CELB	1.092	CENF	1.072	JAGUARI	1.000
13	XANXERÊ	1.106	ESCELSA	1.074	DMEPC	1.024
14	ELETROACRE	1.108	BANDEIRANTE 2	1.074	MOCOCA	1.073
15	SANTA CRUZ	1.109	CSPE	1.077	BANDEIRANTE 2	1.096
16	CENF	1.122	BOA VISTA	1.080	XANXERÊ	1.116
17	DMEPC	1.124	PIRATININGA	1.081	CELB	1.120
18	SAELPA	1.125	ELEKTRO	1.082	CFLO	1.138
19	CEEE	1.130	MOCOCA	1.083	COSERN	1.144
20	COPEL	1.135	COELBA	1.084	CELPA	1.153
21	CEPISA	1.136	SANTA CRUZ	1.088	CELESC	1.170
22	CELTINS	1.149	ELETROCAR	1.090	NACIONAL	1.171
23	CELPA	1.154	CELPE	1.090	ELEKTRO	1.183
24	ELN/AM (MANAUS)	1.165	CPFL	1.092	CSPE	1.206
25	CELESC	1.180	ENERGIPE	1.093	BOA VISTA	1.217
26	CEMAR	1.192	AES-SUL	1.093	ENERGIPE	1.221
27	CEAL	1.197	CEPISA	1.093	CELPE	1.233
28	COSERN	1.200	CERON	1.094	SANTA MARIA	1.233
29	CELG	1.201	CELTINS	1.095	CERON	1.258
30	CSPE	1.205	DMEPC	1.096	SAELPA	1.259
31	CAIUÁ	1.211	SAELPA	1.097	CENF	1.266
32	V. PARANAPANEMA	1.215	CFLO	1.101	ESCELSA	1.274
33	ELEKTRO	1.254	SANTA MARIA	1.101	COELBA	1.284
34	CELPE	1.257	CEB	1.106	CEEE	1.337
35	AES-SUL	1.268	NACIONAL	1.113	CEMAR	1.340
36	ESCELSA	1.269	CERJ	1.115	CEB	1.379
37	BANDEIRANTE 2	1.270	CEMAT	1.127	CEMAT	1.437
38	BRAGANTINA	1.276	CELPA	1.129	CEAL	1.449
39	MOCOCA	1.283	COPEL	1.132	COPEL	1.499
40	CPFL	1.302	CEEE	1.133	CERJ	1.522
41	NACIONAL	1.304	CELG	1.140	CEPISA	1.577
42	CERJ	1.318	JAGUARI	1.147	BRAGANTINA	1.600
43	BOA VISTA	1.354	CAIUÁ	1.148	ENERSUL	1.618
44	PIRATININGA	1.389	BRAGANTINA	1.151	V. PARANAPANEMA	1.647
45	ELETROCAR	1.409	ELETROPAULO	1.155	SANTA CRUZ	1.656
46	JAGUARI	1.415	V. PARANAPANEMA	1.179	CELG	1.692
47	CEB	1.768	XANXERÊ	1.196	CAIUÁ	1.733
48	LIGHT	1.830	CELESC	1.283	CAT-LEO	2.174
49	ELETROPAULO	1.986	CEMIG	1.506	CELTINS	2.381
	Mean	1.202	*Mean*	1.110	*Mean*	1.283
	Std. Deviation	0.217	*Std. Deviation*	0.072	*Std. Deviation*	0.302
	25% Percentile	1.106	*25% Percentile*	1.074	*25% Percentile*	1.024
	75% Percentile	1.270	*75% Percentile*	1.127	*75% Percentile*	1.437

Table 4-6. Regression Results

	GLM		OLS	
Variable	*Coefficient*	*Marginal Effect*	*ANEELvsSFA*	*ANEELvsDEA*
Industrial share	-3.466**	-0.741**	-0.728***	-0.561**
	(1.560)	(0.339)	(0.156)	(0.271)
Income (ln)	1.223***	0.262**	0.132**	0.151*
	(0.468)	(0.103)	(0.050)	(0.075)
Size (ln)	0.313*	0.067	0.048*	0.039
	(0.190)	(0.041)	(0.027)	(0.028)
Consumption	0.011	0.002	0.001	0.003
	(0.018)	(0.004)	(0.002)	(0.002)
Growth	0.003	0.001	-0.001	0.001
	(0.016)	(0.003)	(0.002)	(0.003)
Customer density (ln)	0.303*	0.065*	0.081***	0.124***
	(0.176)	(0.038)	(0.023)	(0.040)
TCU monitoring	-0.694	-0.156	-0.058	-0.078
	(0.560)	(0.132)	(0.067)	(0.104)
Public company	0.144	0.030	-0.075	0.078
	(0.488)	(0.102)	(0.063)	(0.085)
Learning	0.094***	0.020***	0.005**	-0.001
	(0.020)	(0.005)	(0.002)	(0.003)
Labor price effect			-0.029	
			(0.097)	
Intercept	-3.515***		0.756***	0.533***
	(1.232)		(0.143)	(0.172)
Statistics				
N	49		49	49
Log pseudolikelihood	-18.376			
R^2			0.634	0.522

Robust standard errors in parentheses

Legend: * p<.1; ** p<.05; *** p<.01

CHAPTER 5
SUMMARY AND CONCLUSIONS

This dissertation is composed of three empirical essays (chapters) on the reforms accomplished in the Brazilian electricity sector. Initially, an event-study methodology is employed to examine the actual behavior of the created autonomous regulatory body, vis a vis the predictions of the theories regarding the pattern of the government intervention in business. In sequence, a parametric benchmarking approach is used to investigate whether the price-cap incentive mechanism effectively lead to performance improvements in the electricity distribution sector, checking for difference in performance between public and private firms, and looking at the possibility of efficiency catch-up. Then, the SFA efficiency estimates and indexes of productivity change, along with efficiency measures provided by a non-parametric benchmarking technique, are utilized to evaluate whether the use of the model company approach in the distribution companies' first periodic tariff review enabled the attainment of the welfare maximizer regulator's rate setting objectives.

The event-study examines the regulator's performance in the Brazilian electricity sector using a methodology specially designed to a regulatory context, which explicitly accounts for the possibility of event anticipation. Despite the more pronounced interests that characterize a developing country's regulatory environment, the results indicate that the regulator has acted relatively independently, with its decisions not favoring a single interest group. The findings are similar to the ones obtained in previous studies that focused in the United Kingdom's context, and do not support the claim that Brazilian regulatory agencies are captured by the industry.

On the contrary, the evidenced unpredictability of regulatory agency's decisions suggests that the regulatory agency has favored different interest groups at different times, supporting the claim that the utility maximizing regulator will not exclusively serve a single economic interest.

The observed unpredictability, on the other hand, reinforces the need of improvements in the regulatory discussion process, with the adoption of measures to increase the transparency and to promote more substantive public hearings.

The study suggests that the need to provide incentives for new investments has had a significant role in the regulatory process. In addition, electricity companies have been compensated for the regulatory risk they face. The estimates indicate that regulatory decisions led to an increase in firms' market value over the period examined and account for part of the difference of the sample securities' performance with respect to the market.

Some specific findings are also worth noting. The adoption of the asset base repositioning cost methodology was not that harmful to distribution companies, as one would anticipate in light of the press coverage related to the issue, and the evidence raises the concern over the objectivity and transparency of the methodology employed in the distribution companies' periodic tariff review, suggesting the need of improvements. Moreover, the results indicate that the Government's proposal to review the regulatory agencies' responsibilities and performance was seen as a step back in the electricity sector regulation and increased the regulatory risk.

The second study confirms the theoretical predictions regarding the impact of incentive regulation on firms' performance. Brazilian electricity distribution companies have experienced high productivity growth rates after the sector reforms, above what was found in a previous study for the period before the reforms. The productivity increment relates to the closing of the efficiency gap present in 1998, and is driven by the performance of privatized and public companies.

Privatized firms responded more aggressively than public firms to the new incentives brought by price-cap regulation, denoting that incentives were higher to profit-oriented managers operating under a shareholders' pressure to quickly recoup the investments made. The study's estimate of privatized firms' incremental annual productivity growth rate (3.36%), on the other hand, brings about the need to tailor specific efficiency improvement incentives to public firms, since it represents not implemented-but-achievable productivity gains, which could have resulted in lower tariffs to customers.

The subset of firms privately owned before the reforms shows up as more efficient, on average, than other firms in the beginning of the period examined. Its productivity growth rate evidenced in the present study, therefore, is consistent with a limited space for efficiency improvements - on operating and maintenance expenses – on the more efficient firms subject to a rate of return regulation scheme. Given the sensibly higher productivity growth rates experienced by other firms, "always private" firms face a decline in their efficiency levels over the period. This research provides another possible explanation. It shows that the observed decline in these firms' mean efficiency level derives, fundamentally, from their low productivity growth in 2003, which might therefore indicate a possible strategic behavior of some of these firms, associated to the periodic aspect of the price-cap incentive regulation scheme.

The results suggest a possible occurrence of strategic behavior of another sort as well. In spite of plausible economies of scope, vertically integrated distribution companies show up as more inefficient than other firms, raising the possibility of cost shifting. Stricter rules regarding cost allocation and/or a closer look at these companies' accounting numbers may be appropriate.

Interestingly, the study reveals that the high performance improvement experienced by privatized firms in the period does not come from mere reductions in costs brought by deterioration in the quality of service provided, a result that also indicates the effectiveness of the quality regulation instruments implemented by the regulator.

All these findings ultimately provide a better understanding of the cost opportunities faced by each firm, and consequently enable the establishment of prices conducive to a greater social welfare. The regulator has had the opportunity to define new electricity distribution prices in the periodic tariff review that started in 2003. On that opportunity, the choice was for the use of the model company approach to estimate each firm's efficient operational costs. This paper's findings provide the basis not only for evaluating the regulator's decisions in those circumstances, notably with respect to their consequences in terms of both distribution of productivity gains among stakeholders and incentives for further efficiency improvements, but also for examining the model company approach itself. The approach's usage is not pacific in the theory and its implementation in the Brazilian context has been disputed among the parties involved.

The performed evaluation of the results obtained with the use of the model company approach reveals that the regulator's objectives might not have been welfare maximizing in some situations.

On the one hand, some firms were considered to be rather more inefficient than shown by both SFA and DEA models, resulting in substantially lower price increases: this result raises concerns over the companies' long-term financial sustainability. On the other hand, the results point to the existence of firms which the regulator's method considered to be much more efficient than suggested by the two widely-used benchmarking methodologies.

The study provides new findings on possible causes for these divergences in the context of a particular regulatory system. The results indicate that firms with a lower proportion of electricity delivered to industrial customers, which serve wealthier consumers and operate in more densely populated areas, had lower bargaining power in the tariff setting and were harmed by getting prices lower than recommended by the economic benchmarking methods. These results are consistent with the economic theory of regulation which posits that political influence affects the level of prices. On the other hand, firms with opposite characteristics had higher bargaining power and benefited from higher prices. The evidence is consistent with an association between per capita income and the effectiveness of residential interest group activity. Moreover, the findings point to a possible inaccuracy of the cost parameters employed in the engineering Model Company approach; the parameters may inaccurately capture the effect of consumers' dispersion (customer density) on firms' operating costs, due to either the technical difficulty in defining the "true" parameter in a context of imperfect and asymmetric information, or a deliberate intention to avoid compensating investors in utilities operating in areas of higher consumer concentration, and to provide extra returns to firms working in less densely populated areas.

This benefit given at the beginning of the tariff review cycle impacted negatively the incentives for efficiency improvements provided to firms which do not appear in the top ten segments of SFA and DEA efficiency ranking. The same disincentive was received by four of the top five firms in the SFA ranking, which could not keep part of the rents brought by their productivity improvements. In sum, the regulator's methodology imposed on firms a one-time adjustment to the virtual company's efficient operating costs, which in some cases were rather different than the ones estimated by the benchmarking methods. Moreover, the rulings (and associated price trajectories) ignored the significant frontier shifts of almost 7% per year revealed by the parametric modeling, a point that would exacerbate the perverse effects of the hypothesized over-evaluations of firms' efficiency.

Interestingly, the findings do not provide support to the hypothesis that the monitoring of the regulator's activities may lead to decisions contrary to firms' interests and increase firms' regulatory risk, one of the possible effects of having an institution supervise the regulator's job. Regulator's decisions were not affected in a systematic way by special oversight. Despite its specificity, the result adds to the literature on the optimal regulatory framework design.

It should be stressed that the results outlined above are robust to the choice of benchmarking methodology (SFA or DEA) to employ as a comparison parameter. Moreover, the results do not support those who are concerned with possible limitations of the SFA methodology. However, for those who are more hesitant to abandon engineering models, at a minimum the present investigation presents a way to promote greater transparency to the process and credibility for the results obtained with the application of the Model Company method. Once the divergences in efficiency assessments are identified, and possible explanatory factors are uncovered, it remains the regulator's job to justify the choices made or demonstrate that the divergences do not come from deficiencies in the application of a particular methodology.

The proposed joint use of a comparative efficiency analysis technique benefits all stakeholders including the regulator; the agency could employ other benchmark techniques to alleviate potential adverse selection problems and consequently come up with more reliable approximations of firms' break-even points. It would then be possible to better exploit the price-cap incentives for efficiency improvements and promote the desired allocation of productivity gains among stakeholders. Note, on this topic, that the redistribution of rents should ideally be based on information regarding the productivity increments of each firm during the whole regulatory period prior to the next review, information that the model company approach alone cannot provide.

The experience so far on setting price caps has indicated that quantitative benchmarking techniques may at least serve as an additional tool to the regulator, whose importance is underscored by information contained in comparisons available from having a large number of companies in the regulated industry. Thus, there appears to be no reason for not using them in the Brazilian electricity distribution industry.

APPENDIX A
DETAILS ON EVENT STUDY'S SAMPLE AND DATA

Table A-1. Missing Observation Problem (Number of computed stock returns missing)

	COPEL	ELETR	ELETB	CEMIG	CESP	LIGHT	CELES	TRACT	EMAE	FCATA	COELCE	TRANP	CERJ	PAULFL
Total missing	0	0	0	0	2	1	4	52	58	119	266	334	382	552
% missing	0.00	0.00	0.00	0.00	0.15	0.07	0.29	3.79	4.23	8.67	19.39	24.34	27.84	40.23
Missing 1998	0	0	0	0	0	1	2	52	13	38	46	196	6	2
Missing 1999	0	0	0	0	0	0	2	0	4	67	51	138	0	8
Missing 2000	0	0	0	0	2	0	0	0	10	8	46	0	55	34
Missing 2001	0	0	0	0	0	0	0	0	2	2	85	0	104	124
Missing 2002	0	0	0	0	0	0	0	0	27	0	24	0	157	226
Missing 2003	0	0	0	0	0	0	0	0	2	4	14	0	60	158

*1: COELCE was not included in the sample because it has a high number of missing observations in all years examined. It was checked the possibility of its inclusion in the regressions for year 2003, but the fact that this security has 38 observations missing in the 2002-2003 period was reducing significantly the total number of observations and preventing the analysis of the significance of some announcements.

Table A-2. Companies in the Sample

COMPANY	**STOCK**	**SECTOR**	**OWNERSHIP**	**ENERGY DELIVERED TO FINAL CONSUMERS (GWh)**	**PARTIC. IN DISTRIB. MARKET**	**ENERGY GENER. (GWh)**	**PARTIC. IN TOTAL ENERGY GENER.**	**TOTAL ENERGY SOLD (GWH)**	**ENERGY BILLED (R$1,000)**
COPEL	PNB	M	Public	17,629.1	5.8%	16,825	4.6%	22,648.1	2,028,705
ELETROPAULO	PN	D	Private	37,424.0	12.2%	-	-	37,424.0	4,732,541
ELETROBRAS	PNB	G*[1]	Public	22,911.7*[2]	7.5%	165,022*[3]	45.1%	211,889.4*[4]	12,222,302
CEMIG	PN	M	Public	37,542.1	12.3%	32,561	8.9%	42,479.1	3,668,206
CESP	PN	G	Public	2,122.7	0.7%	32,505	8.9%	31,526.7	1,416,175
LIGHT	ON	D	Private	23,783.9	7.8%	4,144	1.1%	23,802.3	3,087,772
CELESC	PNB	D	Public	12,006.3	3.9%	374	0.1%	12,203.6	1,233,600
TRACTEBEL	ON	G	Private	21.9	-	18,605	5.1%	22.178,7	826,093
EMAE	PN	G	Public	-	-	2,614	0.7%	3,689.3	167,985
FCATAGUAZES	PNA	D	Private	1,005.9	0.3%	233	0.1%	1,036.7	132,745
TRANSM. PAULISTA	PN	T	Public	-	-	-	-	-	650,148
CERJ	ON	D	Private	7,325.9	2.4%	241	0.1%	7.656.5	1,085,935
Total					52.9%		74.7%		

Source: Setor Eletrico – Ranking 2001 – Cadernos de Infra-Estrutura BNDES.
- "D" stands for Distribution; "G" for Generation; "T" for Transmission; and "M" for mixed companies (vertically integrated).
*1: Although the energy delivered to final customers is very representative, it accounts for only 10.8% of the total energy sold by the company.
*2: Energy delivered by Chesf (7,546.3), Eletronorte (14,963.8) and Eletronuclear (401,6).
*3: It does not include the energy from Eletronuclear and CGTEE.
*4: It does not include the energy from Eletronuclear and CGTEE. It incorporates, however, the energy from Itaipu.

APPENDIX B
SFA AND DEA EFFICIENCY INDEXES

	SFA						DEA					
COMPANY	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*
AES-SUL	1.062	1.056	1.076	1.078	1.101	1.093	1.000	1.000	1.000	1.000	1.000	1.000
BANDEIRANTE	1.378	1.205	1.146				1.000	1.000	1.000			
BANDEIRANTE 2					1.077	1.074					1.000	1.096
BOA VISTA	1.071	1.101	1.057	1.046	1.085	1.080	1.238	1.381	1.333	1.196	1.205	1.217
BRAGANTINA	1.079	1.091	1.121	1.120	1.128	1.151	1.325	1.294	1.575	1.623	1.629	1.600
CAIUÁ	1.101	1.107	1.106	1.149	1.132	1.148	1.397	1.364	1.517	1.639	1.692	1.733
CAT-LEO	1.073	1.066	1.078	1.075	1.066	1.057	1.869	1.582	1.873	2.024	1.946	2.174
CEAL	1.090	1.079	1.084	1.073	1.071	1.070	1.575	1.464	1.555	1.656	1.664	1.449
CEB	1.113	1.096	1.103	1.105	1.097	1.106	1.443	1.376	1.359	1.295	1.393	1.379
CEEE	1.154	1.121	1.113	1.161	1.174	1.133	1.520	1.447	1.451	1.372	1.397	1.337
CELB	1.110	1.094	1.083	1.065	1.063	1.059	1.460	1.357	1.361	1.481	1.418	1.120
CELESC	1.424	1.358	1.353	1.304	1.512	1.283	1.572	1.447	1.420	1.218	1.261	1.170
CELG	1.065	1.135	1.171	1.181	1.126	1.140	1.536	1.515	1.828	1.984	1.761	1.692
CELPA	1.092	1.165	1.176	1.188	1.151	1.129	1.412	1.333	1.239	1.136	1.217	1.153
CELPE	1.227	1.202	1.124	1.098	1.102	1.090	1.381	1.304	1.307	1.387	1.399	1.233
CELTINS	1.089	1.096	1.085	1.118	1.100	1.095	2.410	2.058	2.257	2.801	2.525	2.381
CEMAR	1.083	1.108	1.123	1.118	1.081	1.072	1.377	1.460	1.451	1.441	1.433	1.340
CEMAT	1.063	1.114	1.135	1.145	1.112	1.127	1.818	1.445	1.618	1.678	1.575	1.437
CEMIG	1.422	1.620	1.593	1.493	1.498	1.506	1.000	1.000	1.000	1.000	1.000	1.000
CENF	1.157	1.124	1.129	1.135	1.090	1.072	1.309	1.309	1.316	1.403	1.441	1.266
CEPISA	1.111	1.139	1.138	1.094	1.129	1.093	1.748	1.706	1.642	1.692	1.724	1.577
CERJ	1.144	1.126	1.116	1.125	1.126	1.115	1.437	1.342	1.534	1.490	1.570	1.522
CERON	1.111	1.118	1.130	1.089	1.095	1.094	1.486	1.406	1.451	1.178	1.277	1.258
CFLO	1.048	1.059	1.079	1.071	1.084	1.101	1.047	1.227	1.107	1.075	1.124	1.138
COELBA	1.104	1.075	1.091	1.121	1.080	1.084	1.486	1.109	1.383	1.709	1.439	1.284
COELCE	1.114	1.097	1.103	1.081	1.068	1.068	1.115	1.060	1.100	1.120	1.096	1.000
COPEL	1.144	1.131	1.148	1.057	1.142	1.132	1.453	1.192	1.330	1.064	1.302	1.499
COSERN	1.081	1.056	1.062	1.064	1.072	1.069	1.300	1.009	1.235	1.326	1.318	1.144
CPFL	1.216	1.185	1.132	1.127	1.129	1.092	1.073	1.000	1.127	1.000	1.004	1.000
ELEKTRO		1.122	1.109	1.081	1.070	1.082		1.174	1.164	1.193	1.004	1.183
ELETROPAULO	1.489	1.289	1.390	1.210	1.131	1.155	1.000	1.000	1.000	1.000	1.000	1.000
MANAUS	1.051	1.098	1.058	1.074	1.061	1.062	1.000	1.160	1.136	1.000	1.000	1.000
ENERGIPE	1.091	1.070	1.098	1.111	1.112	1.093	1.342	1.062	1.316	1.404	1.387	1.221
ENERSUL	1.074	1.080	1.085	1.068	1.066	1.065	1.773	1.475	1.748	1.783	1.712	1.618
ESCELSA	1.108	1.135	1.114	1.095	1.078	1.074	1.208	1.074	1.215	1.295	1.171	1.274
LIGHT	1.233	1.179	1.148	1.131	1.105	1.069	1.000	1.000	1.055	1.000	1.000	1.000
NACIONAL	1.065	1.075	1.086	1.063	1.088	1.113	1.000	1.088	1.112	1.116	1.189	1.171
PIRATININGA					1.127	1.081					1.000	1.000
RGE	1.049	1.059	1.064	1.055	1.057	1.045	1.499	1.000	1.142	1.133	1.092	1.000
SAELPA	1.088	1.083	1.099	1.100	1.103	1.097	1.546	1.264	1.502	1.616	1.553	1.259
SANTA CRUZ	1.080	1.071	1.078	1.091	1.077	1.088	1.328	1.222	1.565	1.799	1.773	1.656
SANTA MARIA	1.091	1.081	1.080	1.103	1.083	1.101	1.182	1.067	1.182	1.282	1.224	1.233
V. PARANAP.	1.090	1.116	1.118	1.147	1.138	1.179	1.295	1.321	1.493	1.567	1.647	1.647
COCEL	1.115	1.087	1.083	1.092	1.100	1.132	1.000	1.000	1.000	1.000	1.000	1.000
CSPE	1.093	1.063	1.052	1.050	1.053	1.077	1.473	1.323	1.222	1.112	1.151	1.206
DMEPC	1.146	1.112	1.115	1.119	1.106	1.096	1.217	1.285	1.292	1.299	1.233	1.024
ELETROACRE	1.038	1.062	1.071	1.065	1.088	1.060	1.000	1.000	1.000	1.000	1.000	1.000
ELETROCAR	1.076	1.054	1.058	1.075	1.087	1.090	1.000	1.000	1.000	1.000	1.000	1.000
JAGUARI	1.135	1.081	1.068	1.091	1.099	1.147	1.000	1.000	1.000	1.000	1.000	1.000
MOCOCA	1.056	1.044	1.045	1.053	1.060	1.083	1.000	1.000	1.000	1.000	1.093	1.073
SULGIPE	1.047	1.066	1.071	1.096	1.103	1.146	1.000	1.181	1.235	1.292	1.321	1.471
CPEE	1.148	1.100	1.055	1.066	1.071	1.101	1.686	1.479	1.064	1.014	1.041	1.145
XANXERÊ	1.103	1.098	1.148	1.143	1.141	1.196	1.000	1.052	1.202	1.172	1.131	1.116
Mean	1.128	1.121	1.121	1.113	1.113	1.111	1.327	1.243	1.314	1.341	1.318	1.279
Std Deviation	0.100	0.092	0.092	0.072	0.084	0.070	0.299	0.224	0.269	0.354	0.314	0.298

APPENDIX C
MALMQUIST TFP INDEXES

COMPANY	*1999/1998*	*2000/1999*	*2001/2000*	*2002/2001*	*2003/2002*	*2003/1998*
AES-SUL	8.48%	6.74%	8.45%	6.64%	10.27%	47.67%
BANDEIRANTE	23.83%	15.79%				43.39%
BANDEIRANTE 2					10.78%	10.78%
BOA VISTA	-0.44%	7.60%	5.24%	0.73%	5.80%	20.16%
BRAGANTINA	2.32%	1.18%	4.77%	4.55%	3.71%	17.61%
CAIUÁ	3.30%	4.37%	0.63%	6.68%	4.36%	20.78%
CAT-LEO	5.25%	3.89%	5.64%	6.83%	7.46%	32.62%
CEAL	6.88%	5.65%	7.59%	7.27%	7.97%	40.72%
CEB	9.12%	7.23%	8.28%	9.83%	8.73%	51.31%
CEEE	11.98%	10.12%	5.06%	8.85%	14.32%	61.21%
CELB	5.51%	5.95%	7.00%	5.65%	6.27%	34.29%
CELESC	13.76%	9.52%	13.50%	-6.77%	28.56%	69.48%
CELG	0.90%	5.12%	8.18%	14.80%	9.06%	43.65%
CELPA	0.00%	6.25%	6.69%	11.63%	10.90%	40.32%
CELPE	10.24%	15.50%	11.40%	8.97%	11.25%	71.96%
CELTINS	2.61%	4.84%	1.26%	6.67%	6.05%	23.23%
CEMAR	3.60%	5.31%	7.83%	11.25%	9.02%	42.70%
CEMAT	1.68%	4.97%	6.52%	11.00%	7.04%	35.08%
CEMIG	-4.75%	12.86%	18.56%	11.59%	11.91%	59.16%
CENF	5.56%	2.47%	2.73%	7.92%	6.17%	27.31%
CEPISA	3.00%	6.23%	10.55%	3.60%	11.25%	39.42%
CERJ	9.74%	9.64%	8.16%	9.28%	11.00%	57.86%
CERON	5.19%	4.97%	10.43%	6.60%	7.83%	40.16%
CFLO	1.00%	0.76%	3.90%	2.44%	2.64%	11.17%
COELBA	11.03%	7.22%	6.18%	13.60%	9.89%	57.77%
COELCE	9.61%	7.74%	11.11%	10.62%	9.98%	59.63%
COPEL	10.56%	8.11%	19.19%	2.18%	12.59%	63.90%
COSERN	9.47%	6.72%	7.51%	7.48%	9.19%	47.40%
CPFL	12.26%	14.95%	11.01%	10.75%	15.22%	82.79%
ELEKTRO		10.16%	12.03%	10.81%	8.90%	48.91%
ELETROPAULO	25.34%	2.29%	26.20%	19.81%	10.63%	114.45%
ELN/AM (MANAUS)	1.37%	11.13%	6.16%	9.46%	8.89%	42.55%
ENERGIPE	8.40%	3.84%	5.76%	7.43%	9.84%	40.48%
ENERSUL	6.10%	6.87%	9.36%	8.47%	9.01%	46.63%
ESCELSA	5.43%	10.50%	10.62%	11.05%	10.24%	57.77%
LIGHT	14.44%	13.09%	12.34%	13.60%	15.04%	90.02%
NACIONAL	1.98%	2.46%	6.13%	1.93%	2.55%	15.92%
PIRATININGA					15.38%	15.38%
RGE	6.43%	7.15%	9.23%	8.76%	10.82%	50.14%
SAELPA	6.36%	4.74%	6.79%	7.18%	8.34%	38.17%
SANTA CRUZ	4.20%	3.26%	3.38%	6.68%	4.80%	24.36%
SANTA MARIA	3.05%	2.53%	0.59%	5.23%	2.26%	14.36%
V. PARANAPANEMA	0.94%	3.77%	1.74%	5.89%	1.79%	14.86%
COCEL	4.13%	2.47%	1.62%	2.22%	0.32%	11.20%
CSPE	5.49%	4.12%	3.57%	3.35%	1.86%	19.76%
DMEPC	5.55%	2.73%	2.65%	4.60%	4.68%	21.86%
ELETROACRE	0.94%	2.98%	4.75%	2.26%	7.44%	19.63%
ELETROCAR	2.89%	0.93%	0.20%	1.46%	2.87%	8.61%
JAGUARI	7.74%	4.61%	1.53%	3.54%	0.16%	18.67%
MOCOCA	2.54%	1.80%	1.65%	2.59%	1.47%	10.45%
SULGIPE	-0.91%	0.90%	-0.62%	1.47%	-1.21%	-0.40%
CPEE	6.48%	6.64%	1.59%	2.55%	0.71%	19.13%
XANXERÊ	1.64%	-3.16%	2.58%	2.83%	-1.85%	1.90%
Mean	6.04%	6.03%	6.94%	6.88%	7.77%	
Cumulative Index	6.04%	12.44%	20.25%	28.52%	38.50%	

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