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Mapping Service Quality in Electricity Distribution in Brazil: An Exploratory Study

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Abstract

This paper aims at characterizing service quality in electricity distribution in Brazil during the period January 2010 to December 2014 at the firm level. For that purpose, indicators pertaining to complaints, average time for solution of problems and consumer satisfaction are considered; the results suggest signs of deterioration in some indicators. In the application of various methods of multivariate statistical analysis, the evidence displays some salient patterns: (a) cluster analysis of the data for the initial and terminal years in 2010 and 2014 suggests that electricity distribution firms cluster into a small number of groups (2 and 3, respectively) that are not directly related to geographic region or firm size; (b) although dynamic factor analysis of the data for each firm over the whole sample period provides mixed evidence, in nearly 43 % of the cases there are important common patterns of indicators within each firm; and (c) canonical correlation analysis of the data for the initial and terminal years indicates a weak association between direct service quality and global perceived satisfaction. The non-negligible quality underperformance and the firm heterogeneity reinforce the relevance of explicitly introducing a quality adjustment factor in the adopted price cap formulas that could potentially consider benchmark firms as an indirect reference.

Keywords: service quality; consumer satisfaction; electricity distribution; Brazil

1 Introduction

The regulation of utilities has increasingly converged towards regulatory mechanisms that are likely to be more conductive to productive efficiency. In fact, the gradual prevalence of price-cap regulation (PCR) in preference to traditional rate-of-return regulatory regimes reflects a consensus with regard to the superior incentive properties of the former regime [see Liston (1991)].

A key element in the implementation of PCR is the productivity offset, which needs to properly capture sector-specific expected productivity changes. In actual regulatory practice, the setting of the so-called X factor is not trivial given issues pertaining to the limited span of regulatory control, structural change in the regulated industry, endogeneity in the economy-wide inflation rate and imperfect competition in the economy [see Bernstein and Sappington (1999, 2000)]. Moreover, it is important to stress that despite its efficiency-inducing properties, a potential side effect of PCR is degradation of service quality. The aforementioned authors contend that quality degradation could justify adjustments in the X factor but do not elaborate the issue in detail. The potential deterioration of service quality motivates the study by Sappington (2003) of U.S. telecommunications, but the results are mixed depending on the quality indicator. Banerjee (2003), on the other hand, investigates the referred sector in terms of 12 service quality indicators and does not find evidence of quality degradation under incentive regulation. The evidence highlights the multidimensional character of service quality that was earlier emphasized, for example, by Lynch et al. (1994). Resende and Façanha (2005) consider the complexity of quality to be characterized by multiple attributes and undertake an efficiency-frontier analysis of U.S. telecommunications that provides evidence of service quality deterioration under PCR.

The relevant literature on service quality, as surveyed in Sappington (2005), reinforces the case for explicit quality regulation. De Fraja and Iozzi (2008) conceptually discuss the possibility of adjusting PCR for quality, whereas Currier (2007a, b) suggests some practical guidelines in that respect.

The present paper aims to map service quality in the context of the Brazilian electricity distribution sector. Previous studies such as those of Resende (2002) and Ramos-Real et al. (2009) indicated a non-negligible degree of heterogeneity across different utilities, with salient cases of underperformance in terms of productive efficiency. The investigation of service quality in Brazilian electricity distribution is still lacking, and the related concerns are important because there are signs, for example substantial labor outsourcing and repeated episodes involving explosions of utility holes, that might indicate quality deterioration. In fact, the possibility of explicit adjustments for quality in the PCR is currently being debated in that sector.

This paper aims to contribute to the literature by providing an exploratory empirical analysis that explicitly considers the multidimensional nature of service quality by means of multivariate statistical analysis techniques that might provide useful information for adjusting the PCR in the electricity distribution sector in Brazil. The paper undertakes three types of analysis:

Cluster analysis in the initial and final years of the sample can identify firms that can be grouped together on the basis of their similarities in terms of a set of service quality indicators;

Dynamic factor analysis for the whole sample, organized as a panel, allows detection of common dimensions across different service quality indicators and firms and thus highlights essential indicators;

Canonical correlation analysis can be used to associate indicators more directly related to quality with those pertaining to consumer satisfaction for the initial and final years of the sample.

The paper is organized as follows. The second section provides basic background on the Brazilian electricity distribution and discusses the data sources and variables used in the empirical analysis. The third section implements multivariate statistical analysis procedures for various quality indicators in terms of cluster analysis, dynamic factor analysis and canonical correlation analysis. The fourth section provides some final comments.

2 Electricity distribution in Brazil

2.1 Basic background

The Brazilian electricity distribution system underwent a significant structural change in 1995 with the privatization of the utilities in that sector. In December 1996, the Brazilian Congress formally created the regulatory agency Agência Nacional de Energia Elétrica (ANEEL)], and more specific regulations aimed at establishing the institutional design were subsequently created. In accordance with international experience, the tariff rule followed a PCR regime; however, the X factors were only fully defined by 2003-4 in some cases. The size of Brazil leads to important regional heterogeneities, and the nature of the production chain adds complexity to the electrical sector. In fact, the generation and transmission segments are potentially favorable to competition , whereas the electricity distribution segment has natural monopoly features [see Mendonça and Dahl (1999) for a discussion of the first phase of reform].

It is worth noting that the Brazilian electrical sector as a whole and its distribution segment in particular currently face significant challenges. In fact, following the energy rationing that took place between June 2001 and February 2002, a second phase of reform began in 2004 with the crucial aim of designing new mechanisms for risk reduction in connection with contracts settled at electricity auctions and those related to investments in new generation plants [see Losekann (2008) and Souza and Legey (2010) for discussions of this second phase of reform]. In fact, more recently, delays in the expansion of generation plants and transmission lines (for example, in the case of the still minor alternative of wind generation) coupled with above-average temperatures and unprecedented low levels of reservoirs in hydroelectric generation plants have increased the risk of rationing. As for the distribution segment, the associated increased challenges faced by hydropower generation have forced a more intense use of the more expensive thermoelectric generation. Accordingly, substantial extraordinary tariff adjustments took place in 2015 that were intended to compensate the distribution firms for unexpected losses. Altogether, the unstable short- and medium-term scenarios in that segment dominate the forefront of the debates; nonetheless, more structural aspects pertaining to productive efficiency and service quality need to be addressed.

2.2 Data sources

The main database used in this study was built upon information provided by the regulatory agency [Agência Nacional de Energia Elétrica – ANEEL] in terms of a specific superintendence [Superintendência de Regulação dos Serviços de Distribuição – SRD]. The regulatory agency manages electricity consumers' complaints by compiling information provided monthly by the call centers of the distribution firms.

The complaints are rated as "valid" or "unfounded" according to the distributors' criteria. However, there are indicators that do not bear such distinction and pertain to the average time in hours required to solve the reported problem. In 2009, the norm pertaining to the quality indicators was changed, and more disaggregated indicators were made available in certain cases. Thus, more disaggregated data became available from 2010 onwards.

Our final sample considers monthly data from January 2010 through December 2014 and relies on the more disaggregated classification. It was possible to consider a sample of 43 firms when we considered cross-sectional analysis of averages for the initial and terminal years' firms as listed in the appendix (the firms were later considered in terms of cluster and canonical correlation analysis). For a balanced panel for the whole period, on the other hand, given omissions it was possible to consider a sample comprising 35 firms. The sample appears to be representative; most major distribution firms are included, and only the Midwest region displays relatively weak coverage.

To assure the comparability of firms of different sizes, the values referring to the number of complaints were normalized by dividing by the total number of customers. Moreover, the average time (in hours) required to solve the problems indicated in the complaints was considered without normalization. Because we consider 14 quality indicators in 3 broad categories, there are 42 indicators pertaining to perceived quality. The following variables referring to types of quality indicators were considered: [1]

- Interruption of the electricity supply;
- Voltage level of the electricity supply;
- Electricity rates;
- Electricity bill;

[1] The broadest list of distribution firms used in the cross-sectional exercises is presented in the appendix.

- Presentation/bill delivery;
- Errors in reading the electricity meter;
- Variation in consumption;
- Charges for irregularities;
- Undue service suspension;
- Unavailability of agency/service branch;
- Attendance;
- Internal installation in the consumer unit;
- Non-compliance with deadlines;
- Other problems

As for consumer satisfaction in general, the regulatory agency also constructs a consumer satisfaction index [*Índice ANEEL de Satisfação do Consumidor-IASC*] that is based on an annual survey of a sample of consumers served by the various distribution firms in Brazil. The indicator is available from a specific superintendence at ANEEL [*Superintendência de Mediação Administrativa, Ouvidoria Setorial e Participação Pública-SMA*]. The total index comprises sub-components pertaining to 5 categories:

- perceived quality (PQUAL): considers questions regarding 17 aspects related to information provided to clients, attendance quality and service reliability;
- perceived value (PVAL): reflects benefit relation; considers 3 questions pertaining to the benefits of energy provision, service quality and quality of customer service;
- satisfaction (SAT): considers 3 questions related to global satisfaction, distance to the ideal firm and global nonconformity;
- confidence in the provider (CONF): considers 4 variables to assess the extent to which the firm is trustworthy;
- fidelity (FID): considers 3 variables to assess the potential willingness of the consumer to switch between energy providers. [2]

Based on ordinal scales and evaluations of customers of a particular distribution firm, the indices are weighted measures that emphasize the distances between best and worst evaluations by the pool of sampled consumers.

In contrast to indicators related to customer complaints, it is worth exploring associations with more direct indicators of service quality. In fact, ANEEL also collects quarterly data on measured technical service quality. The indicators for particular distribution firms are averages of sampled consuming units and thus have a somewhat aggregate nature. We have obtained five of those indicators:

[2] Given the typical natural monopoly feature of electricity distribution, it is unclear whether in practice superposition of concession areas may occur in rare cases.

- Interruption duration by the consuming unit for interruptions greater than or equal to 3 minutes in duration [*duração equivalente de interrupção por unidade consumidora*-DEC);
- Interruption frequency by consuming unit for interruptions greater than or equal to 3 minutes in duration [*frequência equivalente de interrupção por unidade consumidora*-FEC];
- Relative duration of breaching of critical voltage; this indicator indicates the percentage of time during which a precarious voltage prevailed with an established limit of0.5 % [*duração relativa da transgressão de tensão crítica* – DRC];
- Relative duration of breaching of precarious voltage; this indicator indicates the percentage of time during which a precarious voltage prevailed with an established limit of 3 % [*duração relativa da transgressão de tensão precária* – DRP];
- Index for consumer units with critical voltage; this indicator indicates the percentage of consuming units with non-zero DRC relative to the total number of consuming units [*índice de unidade consumidora com tensão crítica* – ICC].

Thus, the empirical analysis used three main databases. The first dataset allows two empirical exercises. The consideration of monthly data regarding perceived service quality and average time for solution enables the generation of a balanced panel of data for the dynamic factor analysis undertaken in section 3.3. On the other hand, a cross-sectional focus on the initial and terminal years permits the use of a broader set of quality indicators in the application of cluster analysis described in section 3.2.

The remaining datasets (referring to direct service quality and also to consumer satisfaction indicators) are used in the application of canonical correlation analysis for the initial and terminal years, as implemented in section 3.4. Because the aforementioned indicators of service quality are available on a quarterly basis, we construct annual averages to match the consumer satisfaction (in terms of annual IASC indicators). The selected indicators and firms will be indicated in each empirical exercise.

3 Empirical analysis

3.1 Introduction

The literature on service quality has previously emphasized the multidimensional nature of the concept; thus, the present paper undertakes a large scale exploratory effort by making use of a variety of multivariate statistical analysis techniques. The purpose is to provide a detailed yet descriptive characterization of service quality in the Brazilian electricity distribution. First, as a preliminary assessment, we consider the evolution of the selected quality indicators by considering (mean) firm-level data obtained in the initial year of the sample (2005) compared to the (mean) firm-level data obtained in the terminal year of the sample (2014). Specifically, we consider one-tailed nonparametric tests for difference in the medians in terms of the Wilcoxon signed rank test for two related samples [see Siegel (1988) for an introduction]. The main comparison is made between 2010 and 2014 to take advantage of a wider availability of perceived quality indicators. The results of this analysis, which were obtained using the software Stata/MP 14.0, are reported in Table 1.

Table 1
Wilcoxon One-Tailed Signed Rank Tests – (Normalized) Complaints (2014 vs. 2010)

Quality indicator	unfounded complaints		valid complaints	
	test statistic	p-value	test statistic	p-value
Interruption of electricity supply	-0.419	0.341	-0.966	0.170
Voltage level of the electricity supply	-2.741**	0.003	-1.717**	0.044
Electricity rates	-2.768**	0.002	-2.528*	0.005
Electricity bill	-0.731	0.236	-1.756*	0.040
Presentation/bill delivery	-1.063	0.146	-2.430**	0.007
Errors in reading the electricity meter	-0.919	0.183	-2.394*	0.008
Consumption variation	-0.205	0.422	-3.924**	0.000
Charges for irregularities	-1.748*	0.041	-1.097	0.140
Undue service suspension	-1.048	0.151	-3.519**	0.000
Unavailability of agency/service branch	-0.048	0.486	-1.957*	0.025
Attendence	-2.325*	0.010	-0.702	0.245
Internal installation in the consumer unit	-2.116**	0.017	-1.964**	0.025
Non compliance with deadlines	-2.889**	0.002	-0.852*	0.202
Other problems	-3.000**	0.001	-3.814**	0.000

Notes: the table presents exact p-values for one-tailed tests.The mean ranks in the two groups (positive or negative ranks) will suggest the direction of the effect when one rejects the null hypothesis of equal median values over the years.
(*) significant positive differences at the 5 % significance level ("quality deterioration") (**) significant negative positive differences at the 5 % significance level ("quality improvement")

Inspection of the table shows significant differences in the medians of many indicators of perceived quality. In fact, the evidence provided by one-tailed tests indicates quality deterioration in 7 of 28 complaint indicators and improvement in 11 of 28 indicators, whereas in the remaining categories no significant differences in medians were detected over the two compared years. Thus, despite the short time interval, one can observe a highly dynamic sector with evidence of underperformance; some examples are salient and consistent with anecdotal evidence, as in the cases of electricity bills, errors in meter reading and non-compliance with deadlines. The measurement is not always made on a monthly basis and sometimes relies on estimates, which can be a problem in Brazil due to the occurrence of highly variable temperatures over the year.[3] Although

[3] We also considered a comparison between average figures from 2005 and 2014, but in that case the available sample consisted of 6 indicators for 31 firms. In terms of complaint indicators, there was

the available data highlight the distinction between unfounded and valid complaints, we initially adopt a cautious approach and do not disregard complaints labeled as unfounded. In fact, one often observes large numbers of complaints in consumer protection agencies. Table 2 indicates some suggestive results with high positive correlations between unfounded and valid complaints related to various indicators. One also observes volatile patterns of associations across the years despite the fact that smoother averaged data were considered in each of the two years.

Table 2
Pairwise correlations between unfounded and valid normalized complaints

Indicator	2010	2014
Interruption of electricity supply	0.424 (0.005)	0.607 (0.000)
Voltage level of the electricity supply	0.905 (0.000)	0.022 (0.886)
Electricity rates	0.922 (0.000)	0,985 (0.000)
Electricity bill	0.657 (0.000)	0.435 (0.000)
Presentation/bill delivery	-0.047 (0.767)	-0.038 (0.809)
Errors in reading the electricity meter	0.314 (0.041)	0.571 (0.000)
Consumption variation	0.236 (0.128)	0,704 (0.000)
Charges for irregularities	0.849 (0.000)	0.636 (0.000)
Undue service suspension	0.150 (0.337)	0.162 (0.298)
Unavailability of agency/service branch	0.248 (0.108)	0.646 (0.000)
Attendence	0.647 (0.000)	0.800 (0.000)
Internal installation in the consumer unit	-0.076 (0.629)	0.715 (0.000)
Non compliance with deadlines	0.384 (0.011)	0.440 (0.003)
Other problems	0.481 (0.001)	0.034 (0,829)

Note: p-values for two-tailed significance tests are reported in parentheses

evidence of quality deterioration in terms of interruption of electricity supply and voltage level of the electricity supply and improvement in the miscellaneous category of other problems. With respect to the average time for solving complaints, there is evidence of deterioration in connection with the voltage level of the electricity supply and other problems and improvement in terms of interruption of the electricity supply.

3.2 Cluster analysis

3.2.1 Basic concepts

The purpose of this sub-section is to identify electricity distribution firms in Brazil that can be grouped in terms of their similarity with respect to a distance criterion as applied to a set of quality indicators.

In general terms, define a set of n objects E = $\{e_1, \ldots, e_n\}$ that one aims to group based upon a certain criterion of similarity conceived with respect to a set of p variables X = $\{x_1,\ldots,x_p\}$. We will focus on a hierarchical agglomerative method that starts with n objects that are successively merged into a smaller number of larger groups to ultimately produce a single aggregate group. The method requires a distance criterion to assess similarity between the different groups. A standard reference is the usual Euclidian distance, given by $d(e_r, e_s) = \sqrt{\sum_{i=1}^{p}(e_{ir} - e_{is})^2}$; another key notion pertains to a centroid that denotes a vector of means of the different variables of interest across the different units of a given partition (j = 1,…, n) and thus would be equal to the original vector itself in the case of an individual unit and for the j-th group would be defined by $o_j = (\bar{x}_1, \ldots, \bar{x}_p)$. A simpler method of agglomeration would rely on the direct comparison of centroids to define the groups to be merged in each iteration, whereas in Ward (1963), one attempts to define aggregation by minimizing the within-group dispersion (WG) and maximizing the between-group dispersion (BG). [4] WG and BG are indicated by

$$WG = \frac{\sum_{j=1}^{k} D_j}{k}$$

where one considers a partition with k groups and defines $D_j = \sum_{i-1}^{n_j} \frac{d^2(e_i, o_j)}{n_j}$, with n_j denoting the number of objects in group j

and

$$BG_j = \sum_{i-1}^{n_j} \frac{d^2(o_j, \bar{o})}{n_j}$$

[4] See Kaufman and Rousseeuw (1990) and Bouroche and Saporta (1998) for overviews.

where $\bar{o} = \sum_{i-1}^{n_j} \frac{o_j}{k}$, The Ward method envisions reduction of the between-group dispersion in each successive iteration.

3.2.2 Empirical results

The results of the cluster analyses of the data for 2010 and 2014 are presented in Figures 1 and 2, respectively. These analyses were implemented using Stata S.E. 14.0 software.

Figure 1
Dendogram - Service Quality in Brazilian Electricity Distribution (for averages in 2010)

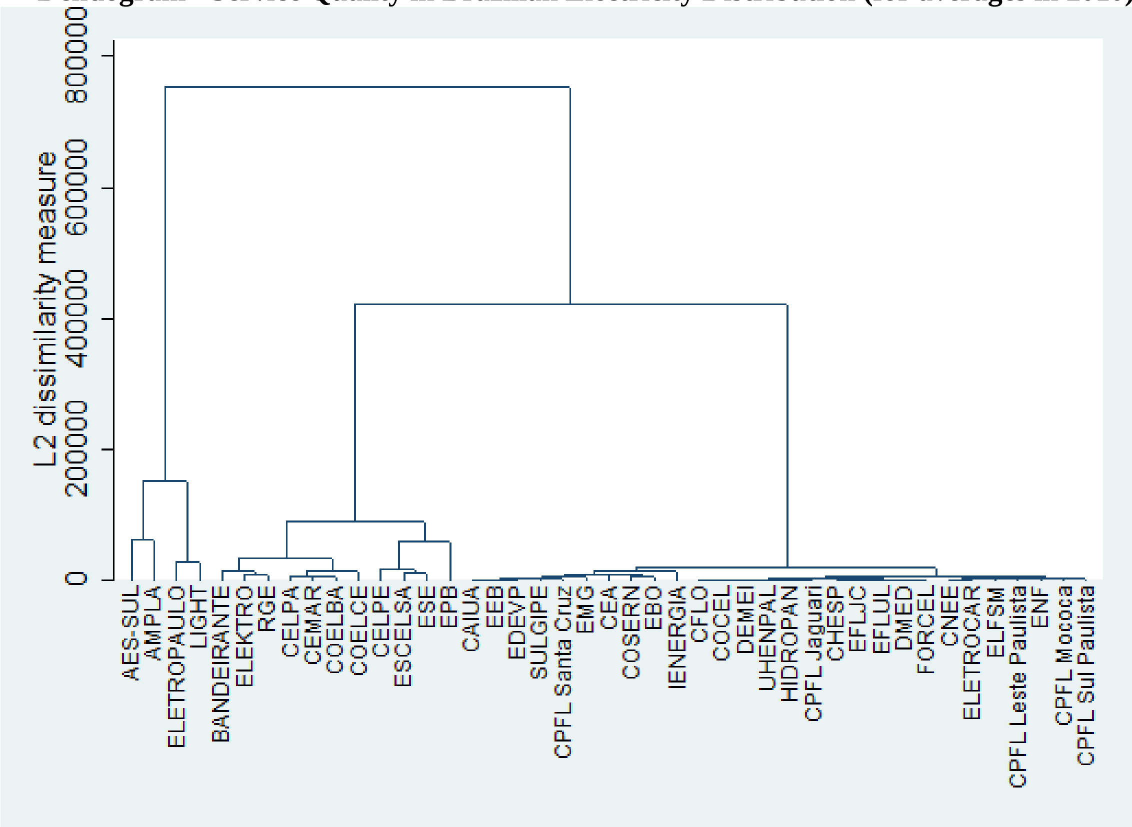
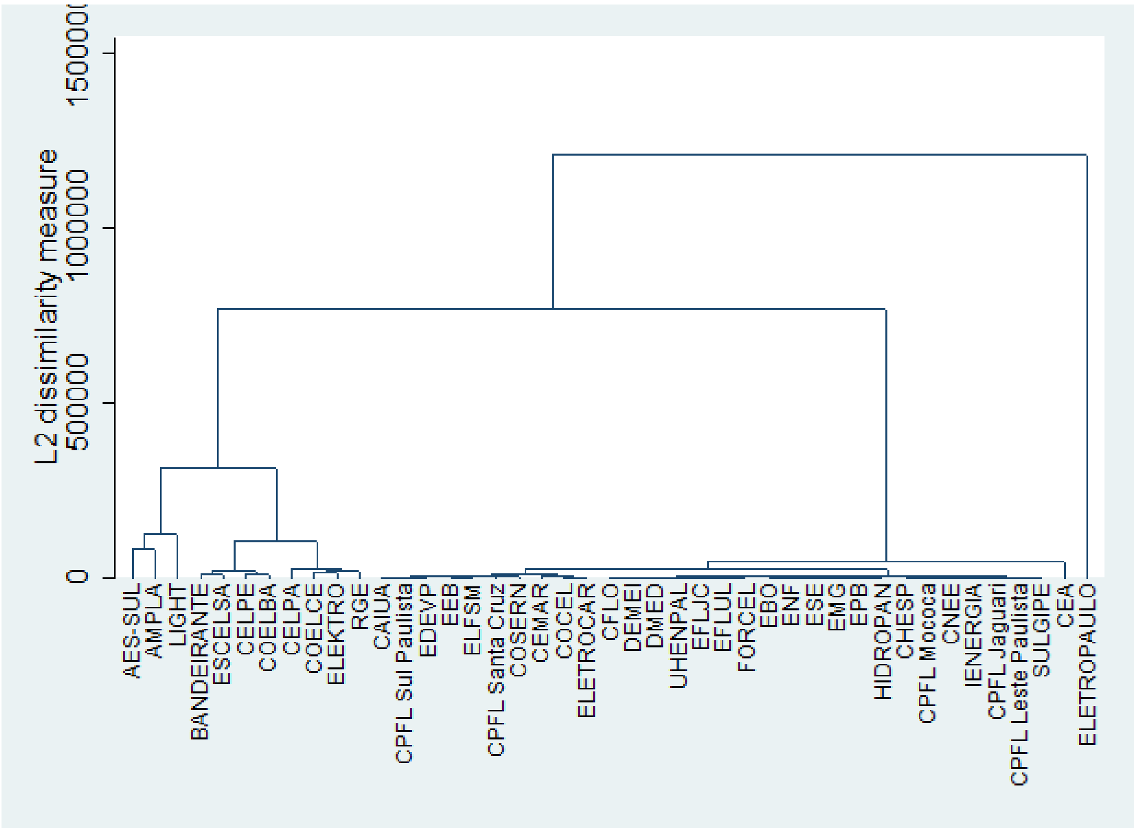


Figure 2
Dendogram - Service Quality in Brazilian Electricity Distribution (for averages in 2014)



Despite the relatively small time span of our analysis, we can observe some contrasts between the initial and terminal years of the sample. The dendogram for 2010, shown in Figure 1, suggests the existence of 3 distinct groups that include sufficiently similar firms in terms of the aforementioned quality indicators. Following the order in the dendogram, one can observe that the third group is especially large in terms of the inclusion of distribution firms and, except for the first group, in which one observes the predominance of firms from the South and Southwest regions, it is not possible to associate the suggested groups with clear-cut regional patterns. As for scale aspects, it is worth noting that we are using normalized variables in the case of complaints; hence, the inclusion of firms with very different scales should not, in principle, constitute an obstacle to inter-firm comparisons. Nevertheless, a potentially relevant aspect pertains to density effects because firms that operate in vast areas instead of supplying more spatially concentrated consumer units may have more difficulty in maintaining adequate quality standards. For example, firms that operate in larger territories such as those in the North region could be less able to explore density advantages, but the results from the cluster analysis do not separate those from firms in the Southeast and Northeast regions.

The results summarized in the dendogram in Figure 2 suggest the existence of 2 groups of firms in 2014. Again, it is not possible to identify clusters of firms that are clearly associated with regions or particular firm sizes. Despite the continental dimensions of Brazil and the presence of significant heterogeneity, the evidence indicates the existence of small groups of firms that can be considered similar in terms of the previously mentioned service quality indicators. Nevertheless, it is interesting to observe the dynamic character of the firms' performance quality; even after a relatively short time interval, it is possible to observe changes in the clustering of firms despite the use of smoothed monthly averages for the initial and terminal years of the sample.

3.3 Dynamic factor analysis

3.3.1 Basic concepts

In this section, we explore the existence of common dimensions across different firms for a given service-quality indicator and across different indicators for a given firm. For that purpose, we consider the dynamic factor approach advanced by Bai and Ng (2002). This approach can be summarized in terms of the general expression for a panel setting with time dimension T and cross-sectional dimension N, as indicated by

$$\underset{(T \times N)}{X} = \underset{(T \times r)}{F^0} \; \underset{(r \times N)}{\Lambda^0} + \underset{(T \times N)}{e} \qquad (1)$$

where X indicates the panel array of the variables under study and r denotes the number of common factors corresponding to the matrix of common factors F^0, with the related factor loadings given by Λ^0. Additionally, **e** stands for an idiosyncratic component of X. The authors, under specific penalty criteria, advance test statistics for determining the optimal number of common factors taking as a reference the relevant asymptotic results in that panel context. Estimates for the individual elements of the matrices F^0 and Λ^0 are obtained upon the solution of the following optimization problem:

$$V(k) = \min_{\Lambda, F^k} (NT)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} (X_{it} - \lambda_i^k F_t^k)^2 \qquad (2)$$

Thus, the common factors and their associated loadings are obtained by the minimization of the sum of the squared residuals. The authors advance various test statistics that embody penalty criteria. In particular, the optimal choice of the number of factors could be considered in terms of the minimization of the following statistics:

$$IC_{p1}(k) = \ln(V(k, \hat{F}^k)) + k(\frac{N+T}{NT})\ln(\frac{NT}{N+T}) \qquad (3)$$

$$IC_{p2}(k) = \ln(V(k, \hat{F}^k)) + k(\frac{N+T}{NT})\ln C_{NT}^2 \qquad (4)$$

where $C_{NT} = \min\{\sqrt{N}, \sqrt{T}\}$.

3.3.2 Empirical results

The empirical implementation of dynamic factor analysis is based on a balanced panel dataset constructed upon monthly observations for the period January 2010 to December 2014. In that application, we are able to consider 35 distribution firms after considering data omissions and variables that had zero values and would therefore not be feasible for use in factor analysis. Thus, bearing in mind these caveats and focusing on valid complaints and average times for the solution of problems whenever feasible, it was possible to consider 20 service quality indicators. [5] The empirical implementation made use of the routine @baing in the software WinRATS Pro. v. 8.3. The related results are reported in Table 4.

[5] There were indicators pertaining to valid complaints and average time for solution in ten categories [interruption of electricity supply, voltage level of the electricity supply, electricity bill, presentation/bill delivery, errors in reading the electricity meter, variation in consumption, noncompliance with deadlines, undue service suspension, attendence, and other problems].

Table 4
Dynamic Factor Analysis – Service Quality – 2010-1/2014-12

Firm	Test statistic	
	IC_{p1}	IC_{p2}
AES-SUL	-0.169 (4)	-0.092 (4)
AMPLA	-0.597 (10)	-0.405 (10)
BANDEIRANTE	-0.597 (10)	-0.406 (10)
CAIUÁ	-0.637 (10)	-0.446 (10)
CELPA	-0.270 (10)	-0.096 (2)
COCEL	0.023 (1)	0.042 (1)
COELBA	-0.497 (10)	-0.305 (10)
CEA	0.009 (1)	0.028 (1)
COELCE	-0.395 (10)	-0.203 (10)
CEMAR	-0.400 (10)	-0.234 (7)
COSERN	-0.978 (10)	-0.786 (10)
CFLO	-0.381 (10)	-0.189 (10)
CHESP	9.3E-04 (1)	0.020 (1)
CPFL Jaguari	-0.048 (1)	-0.029 (1)
CPFL Leste Paulista	0.038 (1)	0.058 (1)
CPFL Santa Cruz	-0.116 (2)	-0.078 (2)
CNEE	-0.254 (3)	-0.197 (2)
CPFL Sul Paulista	-0.008 (1)	0.012 (1)
SULGIPE	-0.310 (10)	-0.118 (10)
DEMEI	- 0.078 (10)	0.024 (1)
DMED	-0.305 (3)	-0.256 (2)
EDVP	-0.462 (10)	-0.270 (10)
EEB	-0.572 (10)	-0.380 (10)
ELEKTRO	-0.308 (10)	-0.119 (5)
ELFSM	-0.084 (10)	0.016 (1)
EBO	-0.158 (10)	-0.029 (2)
EMG	-1.238 (10)	-1.047 (10)
ENF	-0.526 (10)	-0.334 (10)
EPB	-1.082 (10)	-0.890 (10)
ESE	-0.472 (10)	-0.281 (10)
ESCELSA	-0.946 (10)	-0.754 (10)
IENERGIA	0.019 (1)	0.038 (1)
LIGHT	-0.615 (10)	-0.423 (10)
AES ELETROPAULO	-0.337 (10)	-0.146 (10)
RGE	-0.486 (10)	-0.294 (10)

Note: the variables used in the analyses were standardized and assumed a maximum k = 10

The evidence is mixed; in 42.86 % of the firms a small number of factors (perhaps 5 or less) capture common dimensions across the aforementioned 20 quality indicators. In other words, in this proportion of firms more homogeneous patterns of quality provision prevail within the firm and the use of synthetic indicators could be more appealing, whereas in the remaining cases one observes very heterogeneous quality performance across the different indicators. It is worth mentioning that the cases of larger within-firm homogeneity are predominantly associated with firms operating in the Southeast and South regions.

3.4 Canonical correlation analysis

3.4.1 Basic concepts

The technique of canonical correlation analysis (CCA) provides an exploratory tool for assessing linear relationships between groups of variables [see Manly (1994)] for an overview]. Consider 2 groups of variables of interest such that one group has p variables X_1, X_2,..., X_p and the other has q variables Y_1, Y_2,..., Y_q. Moreover, define linear combinations of the original variables as follows:

$$U_1 = a_{11} X_1 + a_{12} X_2 + ... + a_{1p} X_p$$

$$U_2 = a_{21} X_1 + a_{22} X_2 + ... + a_{2p} X_p$$

$$U_r = a_{r1} X_1 + a_{r2} X_2 + ... + a_{rp} X_p$$

and

$$V_1 = b_{11} Y_1 + b_{12} Y_2 + ... + b_{1q} Y_q$$

$$V_2 = b_{21} Y_1 + b_{22} Y_2 + ... + b_{2q} Y_q$$

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$$V_r = b_{r1} Y_1 + b_{r2} Y_2 + ... + b_{rq} Y_q$$

CCA considers r pairs of canonical variates such that the correlation between U_1 and V_1 is maximal, whereas for posterior pairs (U_i, V_i) the correlation is maximal subject to the restriction of no correlation with previous considered pairs. CCA is somewhat analogous to principal components analysis, but the reference criterion relates to correlation and not to variance as in the latter. A second difference refers to the interpretation of the loadings indicated in the previous equations. The signs of those coefficients can lead to misleading interpretations given specific patterns of correlation between the variables of the two groups. Possible guidelines are suggested by Alpert and Peterson (1972) and Manly (1994). For example: [6]

i. Consider the correlation between the canonical variate and the original variables of the related group;
ii. Consider a graph of the association between the first canonical variates of the different groups (U_1 and V_1) to detect strong idiosyncratic patterns in individual behavior.

It is important to stress that, as emphasized by Iacobucci et al. (1994, 1995), there are differences between the concepts of service quality and consumer satisfaction. In the next sub-section, we explore the association of a group of more direct and objective quality indicators with a group of variables that portray different aspects of perceived quality.

3.4.2 Empirical results

The analysis of the indicators described below is undertaken for the same set of firms listed in the appendix and considered in the cluster analysis of section 3.2 in terms of cross-sectional analysis for the initial and terminal years of the sample (2010 and 2014, respectively).

The coefficients for the canonical correlation analysis are presented below for the two groups of variables. The more direct service quality indicators are represented by DEC, FEC, DRC, DRP and ICC, whereas the second group comprises consumer satisfaction indicators represented by sub-components of the IASC index. The analysis concentrates on the linear combinations associated with significant canonical correlations; the related Wilk´s tests are reported in Table 5.

[6] Applications of CCA that are more connected with economic studies are not very common. In this paper, we consider a conceptual discussion and an empirical strategy similar to those considered in Resende (2007).

Table 5
Wilk's test Indicating that the remaining canonical correlations are zero

Canonical correlation	test statistic	distribution under null hypothesis	p-value
2010			
1	1.951	F(25,124)	0.009
2	0.930	F(16,104)	0.537
3	0.687	F(9,85)	0.719
4	0.469	F(4,72)	0.758
5	0.032	F(1,37)	0.576
2014			
Canonical correlation	test statistic	distribution under null hypothesis	p-value
1	0.477	F(25,124)	0.358
2	0.801	F(16,104)	0.947
3	0.918	F(9,85)	0.959
4	0.971	F(4,72)	0.896
5	0.993	F(1,37)	0.608

The evidence for 2010 indicates that only the first canonical correlation is statistically significant. The results for the two groups of variables are as follows:

U_1 = - 0.707 DEC + 0.492 FEC – 0.192 DRC - 0.137 DRP + 0.040 ICC

first canonical correlation: 0.749

V_1 = 0.071 CONF + 0.062 FID + 0.013 PQUAL - 0.010 SAT – 0.039 VALUE

In contrast, the evidence for 2014 suggests that no canonical correlation is statistically significant and that the first canonical covariates reported below have limited relevance. It is worth mentioning that despite the relatively small time interval the obtained results are not stable; thus, one is dealing with a highly dynamic sector.

U_1 = - 0.934 DEC + 0.150 FEC + 0.044 DRC - 0.104 DRP + 0.004 ICC

first canonical correlation: 0.636

V_1 = 0.021 CONF + 0.014 FID - 0.036 PQUAL + 0.126 SAT + 0.011 VALUE

To facilitate the interpretation of the results, Table 6 presents the correlations between the canonical variates and the original variables in the related group

Table 6
Correlation between canonical variates and original variables

2010					
	DEC	**FEC**	**DRC**	**DRP**	**ICC**
U_1	-0.919 (0.000)	-0.654 (0.000)	-0.542 (0.000)	-0.841 (0.000)	-0.464 (0.002)
	CONF	**FID**	**PQUAL**	**SAT**	**PVAL**
V_1	0.912 (0.000)	0.811 (0.000)	0.795 (0.000)	0.778 (0.000)	0.235 (0.130)
2014					
	DEC	**FEC**	**DRC**	**DRP**	**ICC**
U_1	-0.971 (0.000)	-0.667 (0.000)	-0.452 (0.002)	-0.670 (0.000)	-0.581 (0.000)
	CONF	**FID**	**PQUAL**	**SAT**	**PVAL**
V_1	0.953 (0.000)	0.512 (0.000)	0.832 (0.000)	0.979 (0.000)	0.271 (0.078)

The correlations of the first canonical variate, U_1, with the original variables of the first group are uniformly high, negative and significant in both 2010 and 2014. The referred linear combinations can be interpreted as an "overall service quality"; interestingly, no particular category displays a dominant role, and therefore the related indicators (DEC, FEC, DRC, DRP and ICC) capture distinct dimensions of service quality. For the second group of indicators referring to consumer satisfaction in terms of sub-components of the IASC index, only perceived value (PVAL) appeared to have limited importance with respect to the first canonical variate. We interpret the first canonical variate for the second group (V_1) as capturing "global consumer satisfaction". The significance tests for the canonical correlations suggest that the comments should focus on 2010, but it is worth mentioning that the results are unstable despite the short time interval.

The final evidence is provided by the scatter plot of the first canonical covariates of the two groups of variables as presented in Figures 3 and 4. The association between "overall service quality" and "global consumer satisfaction" does not seem to be especially strong, although it displays some positive relationship. The result is not entirely surprising because the underlying more direct service quality indicators are aggregated and do not capture all dimensions of typical consumer dissatisfaction. Perhaps regulatory practice should take into account the "voice of consumers", as suggested by Iacobucci et al. (1995) by explicitly considering synthetic consumer satisfaction indicators deemed representative.

Figure 3
Correlation between canonical variates – 2010

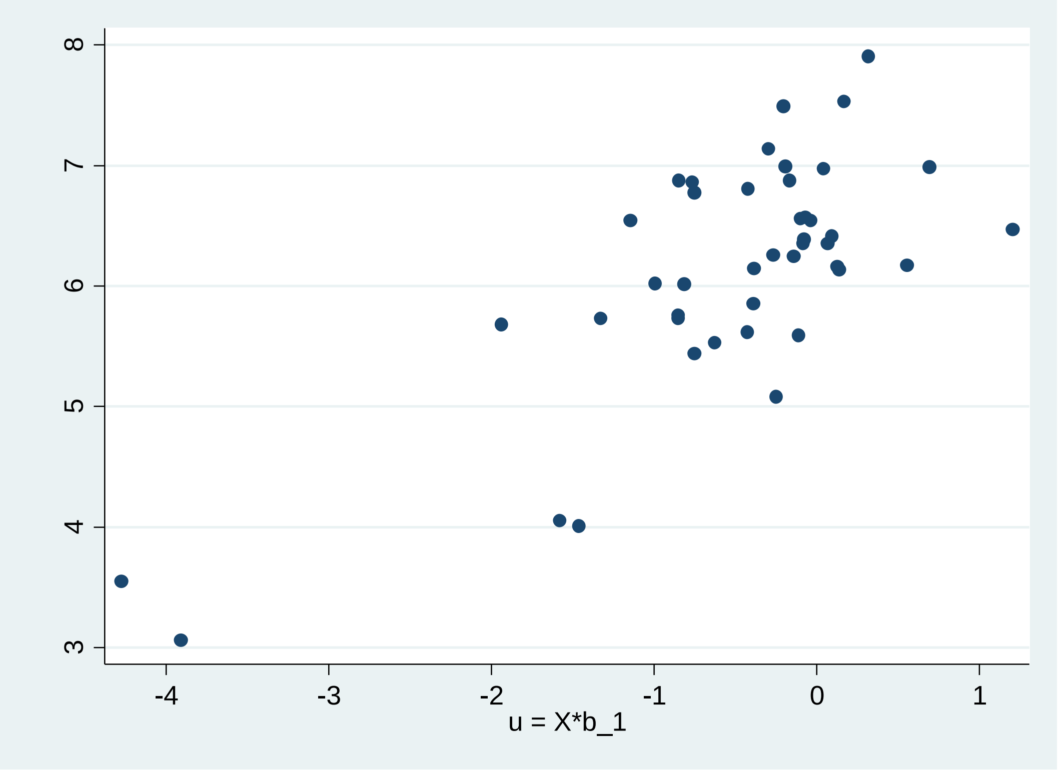
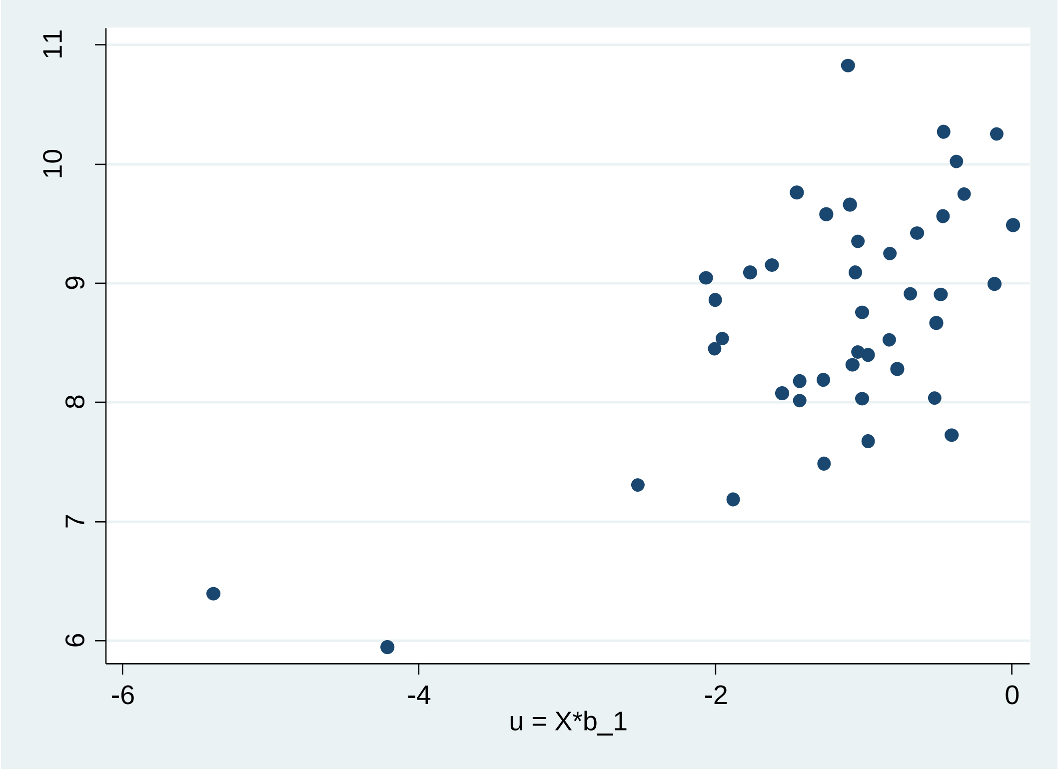


Figure 4
Correlation between canonical variates – 2014



3.5 Quality and yardstick regulation

The explicit consideration of a quality adjustment factor in the price cap formula (the Q factor) slowly began to occur in 2012 in the case of some Brazilian distribution firms. In fact, the norms established by the regulatory agency ANEEL were gradually implemented given the different tariff review cycles and dates of the contracts. However, the initiative initially had limited scope given its reliance on only two technical indicators (DEC and FEC). The methodology was further improved to take into account aspects related to consumer satisfaction; the current methodology, which was applied to some distribution firms in 2015, is described in a technical note in ANEEL (2015).

The methodology embodies some yardstick motivation to the extent that one defines increasing values of the factor Q as the selected quality indicators improve, with transitional values adjusted until 2020. The price cap formula considers an overall adjustment factor comprising a productivity component (Pd), a quality component (Q) and a component reflecting the evolution of operating costs (T) such that X = Pd + Q + T. [7]

The basic weighting structure for the Q factor contrasts technical and commercial indicators as follows:

$$Q = 0.7\ Q_{TECH} + 0.3\ Q_{COM}$$

Moreover, the two categories are respectively contemplated in terms of 7 indicators (DEC, FEC, FER, IASC, INS, IAb and ICO). In this list of indicators, FER stands for equivalent frequency of complaints, INS denotes an indicator for the level of telephone attendance service, IAb indicates interruptions in telephone attendance, and ICO stands for an indicator pertaining to busy calls in the telephone attendance service. It is worth noting that some of the additional indicators were only recently developed. The general weighting scheme embodies the following disaggregated structure:

$$Q = 0.50\ Q_{DEC} + 0.20\ Q_{FEC} + 0.10\ Q_{FER} + 0.10\ Q_{IASC} + 0.04\ Q_{INS} + 0.03\ Q_{IAb} + 0.03\ Q_{ICO}$$

[7] Usually X refers only to the productivity offset, but in the case of the Brazilian electricity distribution the X factor refers to the aggregate concept comprising the referred sub-components.

Thus, the formula assigns dominant weights for “technical” indicators (based on DEC and FEC), whereas the remaining “commercial” indicators even provide some role for apparently secondary problems related to the quality of telephone calls handled by call centers. [8]

In the case of smaller firms with fewer than 60000 consuming units, the implementation of call centers for customer service is not compulsory, and thus a smaller number of indicators is considered, as follows:

$$Q = 0.50\ Q_{DEC} + 0.20\ Q_{FEC} + 0.15\ Q_{FER} + 0.15\ Q_{IASC}$$

The final step involves assigning increasing Q factors for firms located in one of the 4 specified ranges for firms complying with standards [best 25% and remaining 75%] and for firms not complying with standards [worst 25% and remaining 75%]. Although the procedures have yardstick motivation to some extent, the choice of quality indicators that precedes the definition of ranges for Q is highly debatable, especially when one observes the limited role played by consumer satisfaction in the previous formulae. The multivariate statistical analysis exercises of the present paper, despite their exploratory character, might motivate additional studies that address the need for better understanding of the underlying dimensions of different quality indicators to advance towards sounder policy recommendations.

[8] The technical note in ANEEL (2015) acknowledges that the classification of the IASC indicator as a commercial one is not entirely accurate.

4 Final Comments

This paper aimed to assess various aspects of service quality in the context of Brazilian electricity distribution. Despite the relatively short time interval studied, it is possible to detect quality deterioration in the case of some indicators. Several salient results emerge from the multivariate statistical analysis:

a) The cluster analysis applied to the initial and terminal years of the sample indicates that a small number of groups can be considered similar with respect to a broad set of indicators pertaining to complaints and average time for complying with complaints. Moreover, there are clear clustering patterns in terms of geographic regions and firm size, and the groups are not entirely stable over time.

b) The dynamic factor analysis of the panel data for the whole period suggests the coexistence of firms with varying degrees of heterogeneity in terms of the aforementioned class of indicator. In the case of many distribution firms, one cannot summarize common dimensions in terms of few unobserved factors. Thus, the observed within-firm heterogeneity suggests that the quest for representative and synthetic quality indicators is not always obvious.

c) The canonical correlation analysis suggests that the association between overall service quality (measured in terms of more direct technical indicators) and global perceived quality is not strong.

Altogether, the stylized facts appear to indicate that quality underperformance and heterogeneity across distribution firms are salient features that can no longer be neglected. Although the significant economic crisis in Brazil in general and the great difficulties experienced by the electricity sector in particular may overshadow the debate on service quality, such issues will need to be addressed at some point. So far, the consideration of a quality adjustment factor (the Q factor) by the Brazilian electricity agency ANEEL has evolved, but the definition of relevant quality indicators and the procedure for setting values for firms with different degrees of performance are still debatable. [9]

The aforementioned challenges suggest some possible avenues for future research:

i) One possible avenue for further research is investigation of synthetic quality indicators, either building upon the disaggregated complaints indicators or perhaps making the case for an effective use of the IASC consumer satisfaction indicators. The reported quality prizes that were granted by ANEEL from 2013-2015 identified some distribution firms with salient positive performance in different categories (for example, SULGIPE and RGE); thus, one could aim to identify benchmark firms that would provide some guidance for setting the Q factor and perhaps designate reference firms that indirectly suggest a tighter criterion than the one that is currently adopted. In fact, as mentioned in the previous section, it is controversial to impose a limited role for consumer satisfaction. Identification of the essential quality dimensions of electricity distribution is a basic requirement if one intends to incorporate quality adjustments in the price cap formula. Although this paper made an exploratory investigation of possible common dimensions across different quality indicators, the discussion of relevant synthetic indicators is, of course, still open, and additional discussion of the relevance of various components to the Q factor is timely. Although the current rules will prevail until 2020, additional assessments pertaining to quality indicators in electricity distribution are welcome.

ii) From a benchmark perspective, it is possible to consider nonparametric efficiency frontiers for quality indicators, as was done in previous studies carried out in the context of telecommunications by Façanha and Resende (2004), Resende and Façanha (2005) and Resende and Tupper (2009). Those relative efficiency measurement approaches, which were based on Data Envelopment Analysis (DEA), potentially allow the identification of reference firms that could be useful as benchmarks.

[9] Currier (2007a) mentions a handful of actual regulatory experiences that implemented the so-called Q factor as reported in Milne (2003).

The actual setting of a Q factor in a PCR rule is a complex task. However, the consideration of a benchmark firm identified by some consensual synthetic quality indicator could provide some guidance. At least, observed deviations in terms of underperformance relative to a benchmark firm could imply some particular Q factor even if the assigned value embodies some discretionary assignment. In any case, the actual regulatory treatment of service quality in Brazil is still recent, and its evaluation and possible improvement deserve additional research. In fact, the positive incentives in terms of labels and symbolic prizes are now jointly adopted with an incentive mechanism incorporated into the Q factor, and the effectiveness of this system still needs to be assessed. On the other hand, punishments in terms of fines did not seem to be binding in the past because the judiciary in Brazil has often been indulgent with firms in various regulated sectors. Clearly, more research is warranted to address the several issues raised in the present paper.

Appendix

List of Firms in the Sample [states in which the firm operates are indicated in brackets]

AES Sul Distribuidora Gaúcha de Energia S.A (AES-SUL) [Rio Grande do Sul]

Ampla Energia e Serviços S.A. (AMPLA) [Rio de Janeiro]

Bandeirante Energia S.A. (BANDEIRANTE) [São Paulo]

CAIUÁ - Distribuição de Energia S.A (CAIUÁ) [São Paulo]

Centrais Elétricas de Carazinho S.A. (ELETROCAR) [Rio Grande do Sul]

Centrais Elétricas do Pará S.A. (CELPA) [Pará]

Companhia Campolarguense de Energia (COCEL) [Paraná]

Companhia de Eletricidade do Estado da Bahia (COELBA) [Bahia]

Companhia Energética do Amapá (CEA) [Amapá]

Companhia Energética do Ceará (COELCE) [Ceará]

Companhia Energética do Maranhão (CEMAR) [Maranhão]

Companhia Energética de Pernambuco (CELPE) [Pernambuco]

Companhia Energética do Rio Grande do Norte (COSERN) [Rio Grande do Norte]

Companhia Força e Luz do Oeste (CFLO) [Paraná]

Companhia Hidroelétrica São Patrocínio (CHESP) [Goiás]

Companhia Jaguari de Energia Elétrica (CPFL Jaguari) [São Paulo]

Companhia Leste Paulista de Energia (CPFL Leste Paulista) [São Paulo] GR3A

Companhia Luz e Força de Mococa (CPFL Mococa) [Minas Gerais and São Paulo]

Companhia Luz e Força Santa Cruz (CPFL Santa Cruz) [Paraná and São Paulo]

Companhia Nacional de Energia Elétrica (CNEE) [São Paulo]

Companhia Sul Paulista de Energia Elétrica (CPFL Sul Paulista) [São Paulo]

Companhia Sul Sergipana de Eletricidade (SULGIPE) [Bahia and Sergipe]

Departamento Municipal de Energia de Ijuí (DEMEI) [Rio Grande do Sul]

DME Distribuição S.A. (DMED) [Minas Gerais]

Empresa de Distribuição de Energia Vale Paranapanema S.A. (EDVP) [São Paulo]

Empresa Elétrica Bragantina (EEB) [São Paulo]

ELEKTRO Eletricidade e Serviços S.A. (ELEKTRO) [São Paulo]

Empresa Força e Luz João Cesa Ltda. (EFLJC) [Santa Catarina]

Empresa Luz e Força Santa Maria (ELFSM) [Espírito Santo]

Energisa Borborema Distribuidora de Energia S.A. (EBO) [Paraíba]

Energisa Minas Gerais Distribuidora de Energia S.A. (EMG) [Minas Gerais]

Energisa Nova Friburgo Distribuidora de Energia S.A.. (ENF) [Rio de Janeiro]

Energisa Paraíba Distribuidora de Energia S.A. (EPB) [Paraíba]

Energisa Sergipe Distribuidora de Energia S.A. (ESE) [Sergipe]

Espírito Santo Centrais Elétricas S. A. (ESCELSA) [Espírito Santo]

Força e Luz Coronel Vivida Ltda. (FORCEL) [Paraná]

Força e Luz de Urussanga Ltda. (EFLUL) [Santa Catarina]

Hidroelétrica Panambi S.A. – HIDROPAN [Rio Grande do Sul]

Iguaçu Distribuidora de Energia Elétrica Ltda (IENERGIA) [Santa Catarina] Light Serviços de Eletricidade S.A. (LIGHT) [Rio de Janeiro]

Metropolitana Eletricidade de São Paulo S.A. (AES ELETROPAULO) [São Paulo]

Nova Palma Energia Ltda. (UHENPAL) [Rio Grande do Sul]

Rio Grande Energia (RGE) [Rio Grande do Sul]

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