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Critical evalutaion of the efficient costs assessment model used in the regulation of Brazilian energy distribution service operator

Crítica do modelo de cálculo do custo eficiente das empresas brasileiras de distribuição de energia elétrica

Evaluación crítica del modelo de evaluación de costos eficiente utilizado en la regulación de los operadores brasileños de servicios de distribución de energía

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Abstract

This study presents a critical view of the Brazilian distribution service operators(DSOs) performance evaluation model conducted in the 4th. Cycle of Periodic Tariff Review (TN 66/2015-SRM/SGT/ANEEL). More mature regulation models were used as parameters for the development of this work, besides the scientific references on the methodology used in Brazil (Data Envelopment Analysis - DEA). Alternative analyzes were developed with the same data used by the regulator to compare the official results and those in this research. The results indicate that measures used by the regulator can be refined through the suggested contributions, among them: removal of variables with zeroed data; inclusion of environmental variables to correct the model; removal of weight restrictions. The results indicate the existence of distortions between theory and other regulation references, and its application in the Brazilian model.

Keywords: Data Envelopment Analysis; Performance; Regulation of the Electric Sector; Distribution of Energy.

Resumo

Este estudo apresenta uma visão crítica do modelo de avaliação do desempenho das empresas de distribuição de energia elétrica brasileiras, realizado no 4º. Ciclo de Revisão Tarifária Periódica (NT 66/2015-SRM/SGT/ANEEL). Utilizaram-se como parâmetros para o desenvolvimento deste trabalho modelos de regulação mais maduros, além das referências científicas sobre a metodologia utilizada no Brasil (*Data Envelopment Analysis* – DEA). Foram desenvolvidas análises alternativas com os mesmos dados utilizados pelo regulador para comparar os resultados oficialmente utilizados com os da presente pesquisa. Os resultados indicam que medidas utilizadas pelo regulador podem ser refinadas por meio das sugestões propostas, estando entre elas: remoção de variáveis com dados zerados; inclusão de variáveis ambientais para correção dos escores de eficiência; não utilização de restrição aos pesos. Os resultados indicam, ainda, a existência de distorções entre teoria e outras referências de regulação e a aplicação utilizada no Brasil.

Palavras-chave: Data Envelopment Analysis; Desempenho; Regulação do Setor Elétrico; Distribuição de Energia.

Resumen

Este estudio presenta visión crítica del modelo de evaluación del desempeño de empresas distribuidoras de electricidad brasileñas, em el 4ª. Ciclo de Tarifa periódica (TN 66/2015-SRM / EST / ANEEL). Los parámetros para el desarrollo de este trabajo son los modelos de regulación más maduros, además de las referencias científicas sobre la metodología utilizada en Brasil (Data Envelopment Analysis - DEA). Análisis se realizaron con los mismos datos utilizados por el regulador para comparar los resultados utilizados oficialmente y la presente investigación. Los resultados indican que las medidas utilizadas por el regulador pueden ser refinadas a través de las sugerencias propuestas, entre ellos: las variables eliminando ponen a cero los datos;

la inclusión de las variables ambientales para la corrección del modelo; remover la restricción de pesos. Los resultados muestran que la existencia de distorsión entre la teoría y otras referencias de regulación, y su aplicación en el modelo brasileño.

Palabras clave: Data envelopment analysis; desempeño; regulación del sector eléctrico; distribución de energia.

1 INTRODUCTION

The challenge of regulating the electricity distribution sector in Brazil involves providing the final consumers energy with fair prices, which are not abusive, and adequately remunerate the distributor. Every year the demand for energy is growing and, in 2015, Brazil had 77 million consumer units (UC), being 85% of them residential units (ABRADEE, 2015). Given the dimensions of the country and diversity of environments (in terms of features, and vegetation concentration of people, etc.) it can be said that the regulation process in Brazil has peculiar characteristics that require well-formulated solutions to enable proper delivery of energy at fair prices.

Historically, the production of electric energy in Brazil was predominantly based on hydroelectric plants due to its characteristics of topography and abundance of water resources of fresh water. This source corresponded to approximately 72% of installed capacity in the country and 85% of consumption in Brazil (ANEEL, 2008). In addition to the geographical aspects, the electricity sector was strongly influenced by political, social and economic configurations, specific to Brazil, being similar in many respects to the settings of other Latin American countries, in terms of capitalism practice (Pase, 2012).

From the 1930s until the end of the 80s, the electricity sector growth was due to public action in order to increase the supply of energy to enable the growth of national infrastructure, providing infrastructure for the industrial park in the country, as well as facilitating the process of urbanization and population access to public services (Pase, 2012). From the 90s on, concomitantly with the initiation of democratic process in Brazil, reforms were initiated in various sectors of the country, among them the inclusion of the private sector in the electricity sector through the

National Privatization Program (PND), which transferred 31% of the capital of state-owned energy companies to the private sector (Gonçalves Júnior, 2007).

In order to enhance the incentive model for Brazilian distribution service operators (DSOs) to reduce their operating costs, the National Electric Energy Agency (ANEEL) implemented in 2011 the methodology entitled Data Envelopment Analysis (DEA), promoting benchmarking among companies. The result of this comparative assessment is an efficiency score and a target goal that must be achieved within the tariff cycle. The use of DEA in the calculation of distribution operating costs was a surprise for the companies in 2010/2011. Its use was consolidated in 2014/2015 through the opening of the Public Hearing n^{o}. 23/2014 and subsequent publication of the final decision (NT 66/2015-SRM / SGT / ANEEL).

DEA developed by Charnes, Cooper and Rhodes (1978) is a well established non-parametric methodology to assess the relative efficiency of a comparable set of entities, called decision-making units (DMUs), with multiple inputs and outputs (Zhu & Cook, 2008). In studies in the energy sector, DEA has been widely used to assess and compare the efficiency of energy industries, particularly in electricity. In addition, with the wave of deregulation in the energy sector since the late 1980s DEA has been accepted as an important frontier technique for benchmarking in many countries, particularly in the distribution of electricity (Jamasb & Pollitt, 2001). For more references of the use of DEA in the electricity sector, see, for example: Weyman-Jones (1991); Bagdadioglu, Price, and Weyman-Jones (1996); and Yunos and Hawdon (1997); Førsund and Kittelsen (1998); Raczka (2001); Kulshreshtha and Parikh (2002); Pacudan and Guzman (2002); Jamasb, Nillesen, and Pollitt (2004); Pombo and Taborda (2006); Vaninsky (2006).

This article discusses the benchmarking model implemented by ANEEL through the Technical Note (TN) 66/2015 - SRM / SGT / ANEEL. It is presented as follows: a brief introduction; then a review of the DEA methodology is made. The third section explains the application of benchmarking techniques in the electricity distribution sector in Brazil; the fourth section briefly explains the methodology of the article; the fifth section provides a discussion of the model used by ANEEL for measure the distribution energy efficient operational costs and some considerations for better implementation. The final section provides the conclusions of the paper.

2 LITERATURE REVIEW

2.1 Data envelopment analysis (DEA): A Brief Overview

In 1978, Charnes, Cooper and Rhodes extended the concept of efficiency by Farrell (1957) and proposed a new methodology to measure the relative efficiency of decision making units (DMUs) using multiple inputs to produce multiple outputs. This methodology was named Data Envelopment Analysis - DEA. The name comes from the surface that is constructed empirically by the data that involves the production observed using a linear surface in parts, under the assumption of convexity and monotonicity.

Through this method, the efficiency of each DMU obtained by h_0, as a higher value of a ratio of weighted outputs and weighted inputs, subject to the condition that the corresponding proportion of each decision-making unit must be less than or equal to 1.

The variables u_r and v_i seen in Model 1 represent, respectively, the weights assigned to r outputs and i inputs. The amount of outputs r (r = 1, ... s) generated using the inputs i (i = 1, ... m) by DMU j (j = 1 ... n) are represented by y_{rj} and $x_{ij,}$ while y_{r0} and x_{i0} quantifies the input/output data of the DMU that is having its efficiency score measured in a specific mathematical programming model.

The fractional model represented by Model 1 searches, for r output (u_r) and i input (v_i), the weights that maximize the output/input ratio of the decision-making unit that is under analysis. The following model must be run once for each DMU, generating its relative efficiency score, as well as information about the benchmarks for the inefficient DMU. h_0 will vary between 0 and 1. Results lower than 1 (h_0 <1) indicate that the DMU under analysis must constrict the input quantities to be used by (1- h_0 *), in order to be considered efficient (h_0 = 1).

Model 1: DEA - model of constant returns to scale (CRS), oriented to the contraction of inputs

$$Max\ h_0 = \frac{\sum_{r=1}^{s} u_r\, y_{r0}}{\sum_{i=1}^{m} v_i\, x_{i0}}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r\, y_{rj}}{\sum_{i=1}^{m} v_i\, x_{ij}} \leq 1, \qquad j = 1, \dots, n$$

$$u_{rj}, v_{ij} \geq 0, \quad r = 1, \dots, s; \quad i = 1, \dots, m \tag{1}$$

As Dyson et al (2001) state, through DEA, any DMU having a maximum output/input ratio appears as efficient, since the optimized weights are chosen. Assuming these ratios are scattered on the whole group, there will be an efficient DMU for each relation.

The mathematical programming above, known as CCR (Charnes, Cooper & Rhodes) or CRS (constant returns to scale) model, can be transformed into a linear form (Model 2), which is called multiplier model. This model is suitable for evaluating the efficiency of DMUs operating with technologies globally characterized by constant returns to scale, but also have their goal of radial reduction of all inputs. The result of this model indicates how much a decision making unit must reduce the amounts of resources consumed x_{i0}, maintaining y_{r0} constant, so that it can be as effective as its peers (reference values). Some slack after this radial reduction of inputs may still exist.

Other than the input orientation presented herein, there is also the possibility of a model that is oriented to output expansion. This model will bring a response to the decision maker on how much each DMU should expand the amounts of produced results, keeping the amount of resources consumed constant.

Model 2 can be transformed, by the theorem of linear programming duality in Model 3 and is called envelopment model. λj is the percentage of participation of each DMU j (j = 1, ... n.) in building a virtual efficient DMU. θ represents the efficiency score of DMU_0. The variables x_{ij}, y_{rj}, x_{i0} e y_{r0} have the same meanings in Models 1 and 2.

Model 2: DEA CRS, input oriented, multiplier model

$$Max\ h_0 = \sum_{r=1}^{s} u_r y_{r0}$$

subject to:

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$
$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \quad j = 1, \dots, n$$
$$u_{rj}, v_{ij} \ge 0, \quad r = 1, \dots, s; \ i = 1, \dots, m \qquad (2)$$

Model 3: DEA CRS, input oriented, envelopment model

$$Min\ \theta$$

subject to:

$$\sum_{j=1}^{n} x_{ij}\lambda_j - x_{i0}\theta \le 0, \quad i = 1, \dots, m$$
$$\sum_{j=1}^{n} y_{rj}\lambda_j \ge y_{r0} \qquad r = 1, \dots, s$$
$$\lambda_j \ge 0, \quad j = 1, \dots, n \qquad (3)$$

In 1984, Banker, Charnes and Cooper extended this approach to technologies that offer variable returns to scale (increasing, constant and decreasing), adding in Model 3 the restriction that the sum of the lambdas is necessarily equal to 1 ($\sum_{j=1}^{n} \lambda_j = 1$). With this VRS (variable returns scale) or BBC model (Banker, Charnes & Cooper), DEA can be used in a large number of cases, without being restricted to constant returns to scale.

The model used by ANEEL in the last two tariff revisions of power distribution companies in Brazil (2011 and 2015), non-decreasing returns to scale (NDRS), is an extension of the previous models. NDRS only allows increasing and constant returns to scale. In this model a variable related to the scale factor (φ) is added to the objective function and constraints in Model 2 (φ>0). To make the Model 3 NDRS the restriction that $\sum_{j=1}^{n} \lambda_j \ge 1$ is added to it. DMUs operating with decreasing returns to scale, in this NDRS model, will have the whole inefficiency (scale and technical) considered as mismanagement under the control of the manager.

2.2 The Benchmarking Models Implemented By ANEEL

Because of the natural monopoly characteristics of the power distribution companies, ANEEL conducts periodic tariff revisions. Rates may be increased or decreased, according to the results from the review, aiming to ensure fairer prices to consumers and maintain adequate returns to companies.

In each periodic tariff review Parcel A, Parcel B and the X Factor are revised. Parcel A refers to non-manageable costs, such as energy purchases, sector charges and transportation of energy. These are classified as non-manageable since they are not under the control of the DSOs (Peano, 2005). Parcel B consists of manageable costs, as follows: return on capital and operating costs. The X Factor measure the sector's productivity gains during the past years. It is important to note that the X Factor is applied only in relation to the manageable costs - Parcel B (Rocha, Bragança, & Camacho, 2007).

In the third tariff review cycle (2011-2014) ANEEL started the use of DEA to measure the DSOs efficient operating costs, with a model divided in two stages. In the first step, the operating costs from the 2nd cycle were updated according to the productivity gains achieved during the period and the growth of consumer units. In the second step, the operating efficient cost was measured by means of a DEA model in two stages and Corrected Ordinary Least Squares - COLS. The database was formed with data from 2004 to 2009, and both DEA and COLS used pooled data. The efficiency scores taken into consideration were generated by averaging the results of the DEA and COLS. Efficient operating cost was then faced with the value obtained in the previous step. The difference between the two values resulted in a value of a factor called T, transition, added to factor X.

The DEA model chosen for the benchmarking analysis in the third cycle was non-decreasing returns to scale (NDRS), oriented to input reduction. ANEEL justified the choice of NDRS stating that DSOs have the advantage of natural monopoly and there is no possibility of decreasing returns to scale. The inputs used in both methodologies, DEA and COLS, were operating costs (staff, administration, materials, outsourced services, taxes, leases and rentals, insurance and others) and the outputs considered were the extent of the distribution network (km), number of consumers and the weighted market (weighted by the share of voltage level in Parcel B). Several different environmental variables were tested to adjust the scores of the DEA model, but the results showed great variability and the results were partially used.

For the fourth cycle of tariff review, the regulator changed the DEA model used in the third review and no longer used COLS. A NDRS DEA model with weight restrictions was implemented with new variables and bootstrapping the results. The database was formed by the average of the years 2011 to 2013 and 61 distribution service operators (DSOs). In the DEA model, the input remained the same as used in the previous cycle, operating costs, however the value of this cost was adjusted by a wage index that is intended to reflect the differences in labor costs in different regions.

The model used as outputs the following variables: total number of consumers, weighted market (measured as in the third cycle), network extension, non- technical losses and CHI (Hours of interruption). The network extension variable was segregated into three different ones: high-voltage, overhead lines and underground network, as shown in Table 1. The reason for this segregation, shown in TN 407/2014 and 66/2015, is that the cost of maintenance of the three types of network is different, causing a direct impact on the operating costs of companies. The last two variables, CHI and NTPs were considered as quality measures and were used in the DEA NDRS model as negative variables.

Table 1
Variables used in DEA Model NDRS 4th. Periodic Tariff Review Cycle of Electricity Distribution of Brazilian Companies

Dimension	Variable	Unit
Distribution network	Underground network	Km
Customer distribution network	Overhead network	Km
	High tension network	Km
	Total of customers	Unit
Market	Weighted market	MWh
Losses	Non-technical losses(PNT)	MWh
Quality	Hours of interruption (CHI)	h

Source: TN 66/2015-SRM / SGT / ANEEL

By applying DEA to the DSOs data, the regulator used the weight restrictions described in Table 2. According to the regulator, the restrictions seek to represent the trade-offs between inputs and outputs.

Table 2

Restrictions Used weights in DEA Model NDRS 4th. Periodic Tariff Review Cycle of Electricity Distribution of Brazilian Companies

Restriction	Lower limit		Ratio		Upper limit
A	1	≤	Underground network/overhead network	≤	2
B	0,58	≤	Overhead network/ Adjusted operational cost	≤	2,2
C	0,4	≤	High tension network/overhead distribution network	≤	1
D	0,001	≤	Weighted market/ Adjusted operational cost	≤	0,06
E	0,03	≤	Total of customers/ Adjusted operational cost	≤	0,145
F	0,01	≤	Non-technical losses/ Adjusted operational cost	≤	0,15
G	0	≤	Hours of interruption/ Adjusted operational cost	≤	0,002

Source: TN 66/2015-SRM / SGT / ANEEL

In order to generate efficiency score intervals, ANEEL proposed the use of the bootstrapping method. For doing this, it has been used the algorithm described in Bogetoft and Otto (2011), with some adjustments made by the regulator. Still, the regulator set the companies' efficiency scores using the ratio between its score and the median of the sector. This adjustment aimed to increase the efficiency scores, seeking to mitigate underestimation errors of the real efficiency of any company. Therefore, all scores were divided by the median sector efficiency scores, but the median was calculated using inefficiencies that were not less than 50%. Based on the results, the median of the sector was calculated as 74%. Efficient operating costs must then be reached at the end of the regulation period, and a limit of 5% per year was set. The regulator also proposed that the calculation of DEA efficiency scores should be remade every two years, while the methodology should be discussed every four years. The efficiency scores calculated by the regulator can be seen in Table 3.

Table 3 – Efficiency Scores calculated with DEA Model NDRS 4th. Periodic Tariff Review Cycle of Electricity Distribution of Brazilian Companies

Company	Efficiency	Company	Efficiency	Company	Efficiency	Company	Efficiency
JAGUARI	100%	CEMAR	87%	EDEVP	70%	COCEL	57%
CSPE	100%	CELPE	86%	BRAGANTINA	69%	CELPA	56%
CELTINS	100%	EMG	83%	CELG	69%	IGUAÇU	56%
RGE	100%	AES SUL	83%	CEMIG	69%	CEB	53%
COELCE	100%	BANDEIRANTE	82%	CHESP	68%	ENF	53%
PIRATININGA	100%	EPB	82%	NACIONAL	68%	HIDROPAN	52%
Nova Palma	100%	SANTA MARIA	81%	CFLO	67%	ELETROACRE	52%
MUXFELDT	100%	JOAO CESA	80%	ENERSUL	67%	ELETROCAR	52%
COELBA	96%	LIGHT	78%	SULGIPE	66%	CERON	51%
CPFL Paulista	95%	SANTA CRUZ	77%	COPEL	64%	URUSSANGA	45%
ELEKTRO	94%	CEMAT	77%	COOPERALIANÇA	63%	CEAL	44%
ELETROPAULO	93%	CAIUA	74%	CELESC	62%	FORCEL	43%
COSERN	92%	EBO	73%	ESE	60%	DME-PC	42%
MOCOCA	91%	ESCELSA	72%	CEPISA	59%	CEEE	42%
CPEE	88%	AMPLA	70%	DEMEI	58%	AME	31%
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	BOA VISTA	23%

Source: TN 66/2015-SRM / SGT / ANEEL

3 METHODOLOGY

This study is based on a documentary research on the model used by the Brazilian regulator of the electricity distribution sector to identify points where there may be improvements, according to theory, simulations or comparison with other more mature models.

A qualitative exploratory approach (Malhotra, 2004) is used to describe the model adopted by the National Electric Energy Agency in the tariff regulation of the Brazilian electricity distribution sector. The documentary research was carried out through the analysis of the official technical notes of the regulatory agency (TN 407/2014-SRE/ANEEL, TN 66/2015-SRM/SGT/ANEEL), obtained from its website, in order to describe and critically analyze the Brazilian electricity distribution regulatory model. The parameters used for this critical analysis are the theoretical references cited in this article, as well as the regulatory models of other countries to which these references refer. Therefore, it can be considered that this research deals with an empirical phenomenon, socially located, and interactive (Kirk & Miller, 1988).

The effort of this paper was made in studying the model that based the calculation of the efficient operational cost of the Brazilian DSos in the 4th Cycle of Tariff Review, since it is the most recent application and therefore deserves further study. Meetings and seminars with distribution companies and specialized consultants, national and international, were carried out with the objective of evaluating the model proposed by ANEEL.

Based on the discussions held at these meetings, NESP research group carried out simulations in order to understand the impact of the methodology applied by the Brazilian regulator. Alternative models were tested in order to compare the impacts of inclusion or exclusion of variables, as well as the adoption or abandonment of certain parameters in the calculation of the efficiency of the Brazilian DSOs. The simulations were performed using the softwares R and PIM-DEA (deasoftware.co.uk) in its version 3.2. Finally, we present the results of the analyzes and the appropriate critics based on these results.

4 DISCUSSION AND RECOMMENDATIONS

4.1 Variables

The first point to be observed in the analysis of the technical note is the presence of zeroed output variables in the database, in particular the underground network variables (rsub) and non-technical losses (PNT). These two variables have a high number of zeros (31 in rsub and 22 in PNT). In addition to these variables, 10 companies do not have values for the variable high voltage network and 6 companies have missing values for CHI.

In the case of the underground network variable it was simulated a DEA model, similar to the one suggested by the regulator, except for the use of this variable. The simulation result shows that this variable has little impact on the final scores, since only one company had a significant change, which justifies the possibility of the exclusion of that variable. The impact of the variable withdrawal is shown in Figure 1.

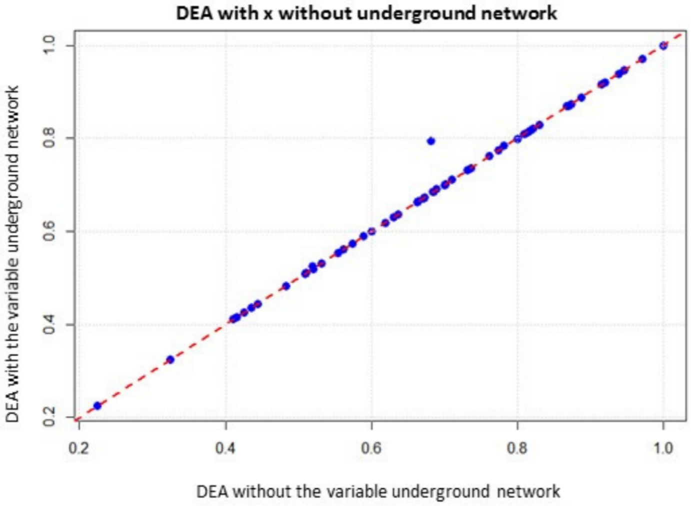

Figure 1
Impact of variable underground network in the model

Still about the model using zeroed data, it is justified the estrangement of the use of it since fundamentally the DEA model (Charnes, Cooper, & Rhodes, 1978) requires positive data for the data and for all companies. This imposition of the methodology comes from the idea that to be comparable the companies analyzed by DEA should have the same inputs to produce the same outputs, but with different quantities. It is possible that companies that do not have values to certain inputs or outputs may be considered inefficient compared to those that have such inputs and outputs.

Thompson, Dharmapala and Thrall (1993) conducted a discussion on the presence of zeros in the database. The authors state that often in the literature zeroed data are replaced by small values added to the zeroed inputs or outputs. It is known that only in the VRS(variable returns to scale) model, from Banker, Charnes and Cooper (1984), constants can be added to outputs in input-oriented models, and added to inputs in output-oriented models, without prejudice to the efficiency scores (Cook & Zhu, 2008). When you have nulls in input and output this device can be used both, but the VRS model can no longer be used but the additive model. Thompson, Dharmapala and Thrall (1993) state that although mathematically it is possible, the results in terms of benchmarking generated by the DEA model does not make sense because an inefficient company may have as benchmark companies that are on the border producing different outputs.

Specifically in the model from TN 66/2015 this means that an inefficient company, for example, can have as benchmark a company that has positive values for underground network and that she does not use this type of network. Moreover, the model presented in TN 66/2015 is a NDRS model, which implies that adding a constant to the outputs can´t be used.

Another important point to note is the inclusion in the model of non-technical losses and quality as non-controllable inputs. According to Bogetoft and Otto (2011), bibliography cited by the regulator, non-controllable inputs can be used as negative outputs in a DEA model. However, for the regulator it is doubtful that non-technical losses and quality are inputs in the DSO production process, as well as the use of these variables as negative variables can skew the results, especially when observing the slacks. Moreover, it is not correct to say that interrupted hours (CHI) and non-technical losses (PNT) are variables that are beyond the control of the manager.

It is suggested as an alternative to consider non-technical losses and quality as undesirable outputs or even the exclusion of same DEA model considered by the regulator or its replacement by the monetary value of the undelivered energy as used in the Finnish regulatory model. It is suggested also to use a single output to networks using some form of weighting that reflects the higher costs of operation and maintenance of all different kinds of network.

It is also considered as the missing variable in the model the one that refers to the number of transformers. This variable has a correlation coefficient of 0.91 with the operating cost, which makes it suitable for its inclusion. Its inclusion also helps to explain the difference in costs of serving rural and urban consumers. The remaining variables as number of substations and transformers (segregated by type) also showed a significant correlation with the operating cost, but at a lower magnitude.

4.2 Environmental variables

In the 4th Cycle the regulator decided not to use any adjustment in the efficiency scores using the environmental characteristics that the company is subjected to. In more mature regulatory models from other countries, analysis of 2nd stage, held between the DEA model generated and environmental variables show that they can help identifying the accuracy of the model created, and whether it is complete with respect to the selected variables.

Authors such as McDonald (2009) and Ray and Ghose (2014) point out that the second-stage analysis is not always the main objective of correcting the scores, but the identification of the magnitude of the effect of environmental variables on efficiency scores. From this information, you can make decisions about policies and actions that minimize the effect of such variables. In addition to this possibility, Bogetoft (2014) states that the second-stage analysis can help identifying missing variables in the model.

For testing the necessity of adjustments in the ANEEL model it was analyzed the effects of environmental variables available in the regulatory database on ANEEL´s scores. The following variables were tested: consumers density, network density, complexity, precipitation, discharge, vegetation, slope and pavimentation. The Spearman correlation indices between the variables are shown in Table 4.

Table 4 Correlation of Environmental Variables with scores Efficiency DEA Model ANEEEL

	ANEEL Score	Customer density	Network density	Complexity	Precipitation	Electrical discharges	Vegetation	Declivity	Pavimentation
ANEEL Score	1	-0,079	-0,071	0,012	-0,332	0,03	-0,092	0,095	0,067
Customer density		1	0,91	-0,044	0,031	0,033	-0,217	0,259	0,783
Network density			1	-0,023	0,079	0,033	-0,233	0,395	0,772
Complexity				1	-0,271	-0,329	0,583	-0,168	-0,224
Precipitation					1	0,65	-0,023	0,114	0,01
Electrical discharges						1	-0,19	0,233	0,079
Vegetation							1	-0,431	-0,488
Declivity								1	0,352
Pavimentation									1

Source:TN 66/2015-SRM / SGT / ANNEL

It can be seen that the environmental variables that have higher correlations are precipitation and electrical discharges (which is expected), vegetation and complexity (0.58) and vegetation and slope (-0.43). Regarding the efficiency score calculated by ANEEL model, only the variable rainfall shows significant correlation (-0.33).

It is important to note that the environmental variables, as well as those chosen to compose the model, also have high dispersion. Thus, the environmental differences between the areas served by the utilities are even more evident. Added to operational differences, these differences threaten the basic premise of applying DEA, that companies should be comparable with regard to their outputs and inputs.

Even if all companies were comparable in terms of outputs and inputs, which seems to be a questionable assertion, given the dispersion of data from companies, the difference in the concession areas expressed by environmental variable precipitation denotes that we must add to the model some other variable to absorb such dispersion.

4.3 Weight restrictions

The model proposed by the regulator used restrictions on inputs and ouputs weights, as showed before. These restrictions come in the form of trade-offs between output and input and are based on Podinovski (2004). Even if we consider that this way of imposing weight restrictions is correct, trade-offs and valuation of inputs and products is combated in Forsund (2012); Also there is the problem of imposition of restrictions on non-controllable variables. It is known that the models in the literature have been proposed for controlled variables and nothing was stated about imposing the weights in non-controllable variables, such as the case of non-technical and quality losses.

Dyson et al. (2001) also argue that the interpretation of results obtained in a model with weight restrictions is not the same as a model without weight restrictions. In a model without weight restrictions the optimal value of θ informs the radial contraction that must be performed on inputs to the DMU (company) to reach the border, or to show itself as efficient as those on the frontier. It turns out, according to Dyson et al. (2001), that this interpretation is no longer valid in a model with weight restrictions. Dyson et al. (2001) states that a model with weight restrictions can´t be regarded as a radial pattern. In addition, the targets and reference companies (benchmark) may be inconsistent.

Another point to be noted is the fact that the weights in a DEA model do not represent the prices of a linear programming model, as the result of the objective function is a score and not income, as Finn Forsund (2012) states:

> Framing the problem of estimation of efficiency within a linear programming model, this paper has raised serious questions about connecting the constraints on weights to intrinsic economic values of outputs and inputs variables. The shadow prices appearing in linear programming and occurring in the ratio definition of efficiency are not measures of economic values. If an overall efficiency measure is sought, then the values have to be found in another way, and treated as exogenous to the programming problem, just like the original definition of overall efficiency in Farrell(1957), introducing input prices. A measure of technical efficiency should not be confused with economic theory. Zero weight appear because data do not contain sufficient information to avoid this ... weighing an output or input is just calculating the marginal contribution of the variable in question to the efficiency score at the optimal solution; this has nothing to do with any external economic value put on the variable. So-called virtual inputs (outputs) are just expressing the contribution to the efficiency score at the optimal solution of the variable in question.

An important point to clarify is that in most scientific papers related to the theme it is mentioned that the restriction is applied to the weights mostly in cases that the number of DMUs (companies) is small compared to the number of inputs and outputs, as already mentioned above. Podinovski (2004) makes this clear when it states that the example used in his paper is typical for this issue: "The initial problems in this example are typical: small data, poor discrimination and many zeros among optimal weights " (Podinovisky, 2004)

The regulator in its proposal does not have this kind of problem, few DMUs. The regulator uses the weight restriction model called Assurance Region II, very unusual in scientific papers because it mixes output and input weights in the same restriction.

The impact depends on the company analyzed and the results can show almost no impact to some of them, like COELCE, CSPE, JAGUARI, MUXFELDT, NOVA PALMA PIRATININGA and RGE, but a high impact like 58.4%, 57.5%, 27,9% for the companies PC-DME, FORCEL and VALE PARANANEMA, among others, respectively. Also when weight restrictions are imposed the largest companies loses 10.2% (Eletropaulo) and 15% (LIGHT) on its efficiency scores.

It is suggested not to use weight restriction and instead the regulator should follow internationally called rule of thumb that the number of DMUs (companies) should be at least 2 times the sum of the number of outputs and inputs used in the analysis. It should be noted that no European regulator uses weight restrictions. The extinction of them raises the average DSOs efficiency by 11.6%. The weight restrictions limit the space of viable goal of the DEA model function solutions. Therefore, each new restriction added to the model tends to reduce the efficiency scores of the companies analyzed.

Figure 2 shows the differences in scores of the model with and without the restrictions on weights proposed by the regulator.

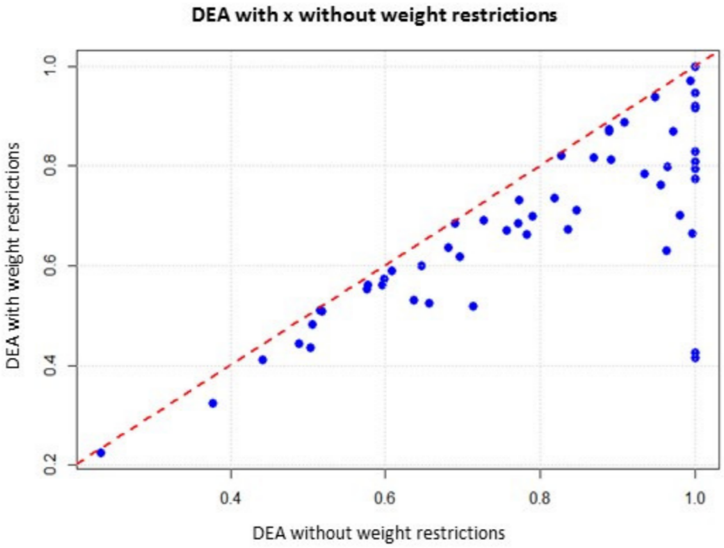

Figure 2
Effect of weight restrictions on model

4.4 Multiple solutions in DEA

The implementation of efficiency scores in goals to be achieved by the Brazilian DSOs during 4th cycle is given in Step 3, while the path in Step 4. Although the proposal is very confusing, using variables in equations that are only explained in the TN a few pages below, an analysis of them is made according to our understanding of what appears in the TN 407/2014.

The DEA models are linear programming models and are designed as such by Charnes, Cooper and Rhodes (1978). The whole linear programming literature (PL) warns of possible multiple optimal solutions that achieve the same objective function value. This means that, in a DEA, the same efficiency score may be achieved by various possible combinations of weights (weights or shadow prices). This is clearly described in various articles published in scientific journals internationally renowned as, for example, in Liang, Wu, Cook and Zhu (2008) and Wu, Yang, Liang (2009).

Liang, Wu, Cook and Zhu (2008), when analyzing the first proposed DEA model, CRS (constant returns to scale) of Charnes, Cooper and Rhodes (1978) state "Note that optimal weights obtained from model (3) (or model 4) are usually not unique". Wu Yang, Liang (2009) analyzing the proposed DEA in 2 stages of Alirezaee and Afsharian (2007) for the ranking of efficient companies, state: "While, in fact, the variables (shadow prices) satisfying model (1) are not always unique. "

This statement, that there can be no single optimal solution in a DEA model, also appears in several books such as Zhu and Cook (2008). Thanassoulis (2003) also points out that the formulation of the problem of linear programming DEA presents a solution within the range of potential viable solutions. That is, for the author, the occurrence of multiple solutions in solving the DEA is a phenomenon of common observation.

The use of multiple inputs and multiple outputs makes the multidimensional model, where the boundary of production makes up a "shell" on the hyperplane. Forsund (2012) states that the extremely efficient units (those with slacks equal to zero) are vertex points in that hyperplane. So the solution to the shadow price of these units is not necessarily unique, because this unit belongs to more than one side of the production frontier. Still, according to the author, as the qualifying restriction is not satisfied for the vertex, the enveloping theorem can´t be used to investigate the impact on the change of data in the evaluated units. Cooper, Seiford and Zhu (2011) point out that, in practice, the solution found by the DEA is an alternative between viable optimal solutions found by switching between the optimal weights of the variables.

This was tested for the case of ANEEL data (Figure 3) and lying is that the weights generated by the R software are different from the weights generated by the PIM-DEA software and even with the use of R there are still significant differences.

The following figure shows the differences between the outputs weights measured with different softwares and for some companies. It is observed that the differences are substantial which prevents the approach envisaged by ANEEL for updating the operating cost. Thus, it can be said that the regulator should seek alternative to perform the update of operating cost values.

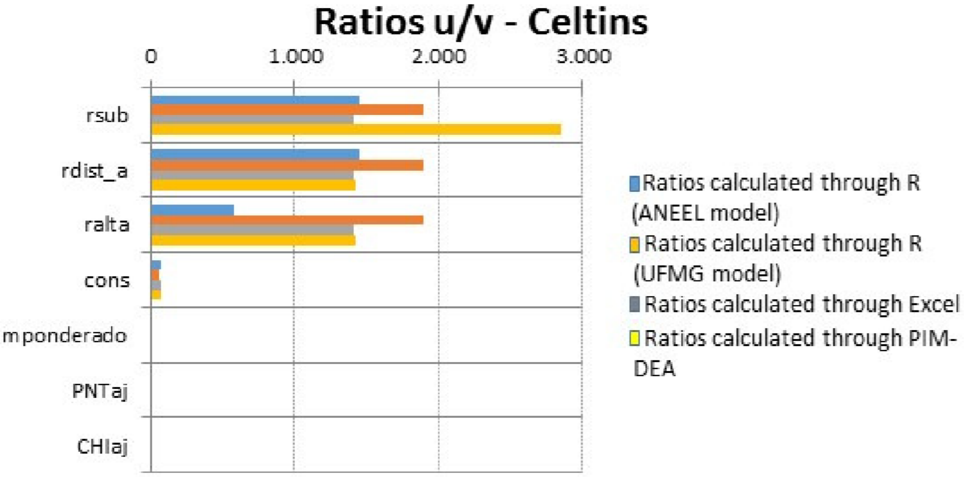

Figure 3
Examples of differences in weights and software for different reasons.

Moreover, and perhaps more importantly, the weights found for the outputs at the time of methodological review - 2014/2015, are weights chosen by the optimization model based on reported data, average years of 2011-2013 of conventional network extension values, underground and overhead, number of consumers, weighted market, interrupted hours (CHI) and non-technical losses. In any event at least one of the variables, the values of the weights are not the same.

Based on the above, multiplicity of optimal solutions and change of the weights in the event of change in values of the outputs, it is believed that the regulator cannot make use of weighs that had been found in one period of the time in future updates of the operating cost.

Any alternative set of weights leads to the same target cost, but if our understanding of the regulator's proposal is correct, that the regulator will use the weights obtained in 2014 to update the values of the actual operating cost to the review date of each company the occurrence of multiple solutions on the weights does not allow this application.

4.5 The problem of dispersion

The regulator establishes for the DEA outputs the following variables: high-voltage network, overhead distribution network, underground distribution network, weighted market, number of consumers, non-technical losses and quality (CHI). In the discussing about network extension the regulator states that the contributions received in order to segregate the rural and urban network are defensible, but present practical difficulties, namely the absence of a classification criteria of rural areas.

The regulator presents a study that aims to prove that the dispersion of the DSOs is already featured in the DEA model, through the definition of outputs. Therefore it is presented the following figure in which lists the ratios Network MT/Consumers and Network MT/MWh with rural network percentage (% rural network).

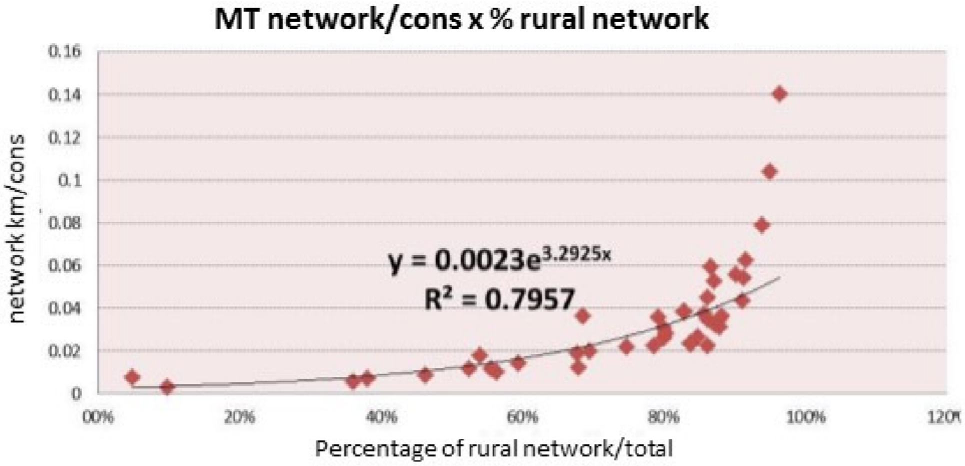

Figure 4
Relationship between Network/Cons and rural network (Source: TN 407/2014 - SRE/ANEEL)

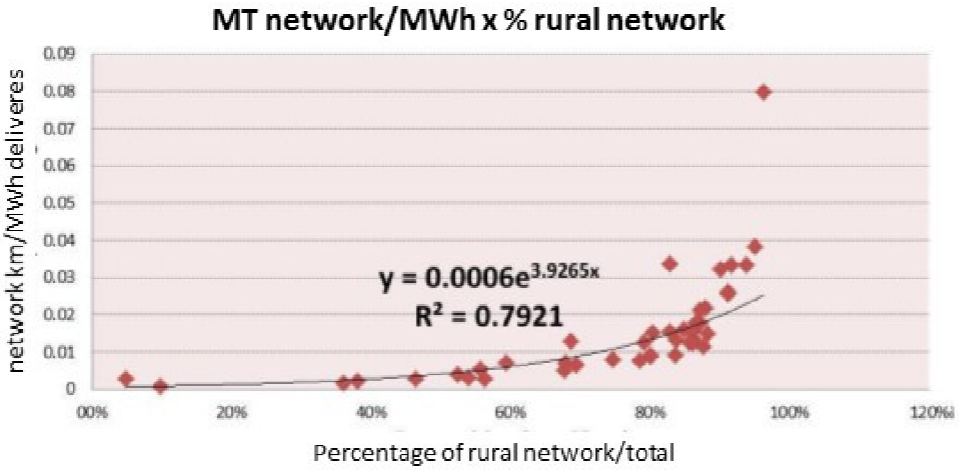

Figure 5
Relationship between Network/MWh and rural network (Source: TN 407/2014 - SRE/ANEEL)

The regulator states, "as can be seen in Figures 4 and 5, the relationship between network and consumer market largely explain the participation of rural networks and thus can portray the different characteristics of concessions. Thus, it was understood that the separation of rural urban network can be omitted without major damage model for calculation of efficiency "(TN 407/2014 - SRE / ANEEL, p. 5).

The Figure show a reasonable fit of the data to the nonlinear model, but also some point away from the same company, as can be seen by the arrows. Although the regulator conclude, based on this study, that the dispersion is represented in the DEA model for relations between network products, market and consumers is demonstrated below that this is a mistake. Emrouznejad and Amin (2009) claim that the use of standard models is clearly incorrect when working with ratios, either in input or output.

It follows, therefore, that if the relationship product1/product2 as network MT/consumers and network MT/MWh were considered in regulatory modeling, it should follow what was proposed in Emrouznejad and Amin (2009). If this is not added to the DEA model proposed by the regulator also there is the need to include variables that express the differences in costs between meeting a rural consumer and serve an urban consumer. The inclusion of variables that express these differences in cost is urgent and indispensable in the proposed model.

5 CONCLUSION

This paper brought a brief review of current regulation model of power distribution in Brazil. It also brought a discussion that allows improvements in the current model, according to references from other countries and theories about DEA. It is possible recognize some evolution in the Brazilian regulatory model, but some other advances can still occur, so as to more accurately reflect the realities of the distribution companies in Brazil, which cover a wide range. In short, it can be pointed out the following proposals for the efficiency calculation model in Brazil:

- Elimination of the underground network variable because it contains a high number of zeros and it is highly correlated with other network variables;
- Inclusion of the variable number of transformers once its high correlated with operating costs;
- Elimination of weight restrictions;
- Consideration of including a variable that takes into account the network dispersion;
- Making a study in depth on the environmental variables that impact the companies' efficiency scores.

Due to the complexity of developing models that can represent complex realities the discussion on the assessment of the Brazilian distribution service operators should continue. This paper brings a well-founded basis that can provide relevant elements for discussion, not being the only points to be evaluated. Further studies should be conducted to present new alternatives that can add value to assessment models currently at the country. The intention is to develop alternatives to the construction of a model that is fair and can provide social and financial return adequate to users and companies from the energy sector.

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