

ESTIMATION OF STOCHASTIC FRONTIER COST EFFICIENCY FOR COMPANIES IN THE ELECTRICITY DISTRIBUTION SECTOR IN BRAZIL

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Abstract

This paper presents the estimation of a cost efficiency stochastic frontier panel for a sample of the Brazilian electricity distribution sector, using in the main function explanatory variables of average operational cost of the companies, such as average salary, cost of energy purchased and volume of energy supplied. In the equation of inefficiency is tested the average duration of the supply interruption per year in hours (DEC) and the average frequency of the supply interruption per year (FEC), as well as the productivity in MWhs sold by employee.

Key words: Technical Efficiency, Stochastic Frontier Cost Model, Econometric Analysis.

JEL classification: C4; C49.

1. Introduction

The application of econometric technique of stochastic frontier analysis of the efficiency of electricity distribution companies started gaining momentum in the mid-90s (Burns and Weyman, 1996). Since then, the international literature has seen an important development, but the most consistent applications are relatively recent.

Just over a decade, technicians of the World Bank (Estache et al., 2002) measured the efficiency Cia. South America, in a case study on international coordination of regulation of the power system. More recently, researchers at the CEPE - Centre for Energy Policy and Economics, Swiss Federal Institute of Technology, Zurich, Switzerland - triggered a succession of studies and research that culminated with a consolidated analysis of benchmarking applied to the distribution of electricity (Filippini et al., 2005 - with financial support from the Swiss Federal Office for Education and Science).

In Brazil, the econometric analysis of stochastic frontier efficiency in the electricity sector, is quite scarce. This paper seeks to contribute to the evolution of research in this area, replicating the methodology used by Tannuri - Pianto, Sousa and Arcoverde (2009).

2. Specification of the econometric model

Between theoretical and empirical references consulted is included Serrato (2007), who developed a survey at the University of Brasilia, to evaluate the use of parametric stochastic frontier method to quantify the cost efficiency of the transmission of energy. Such research has produced a number of pioneering and enlightening about the power transmission market in Brazil, especially as the cost efficiency of enterprises information.

The author in question shows that the parametric method for stochastic frontier can portray in quantitative values, the behavior of the transmission market in Brazil, with the use

of this promising methodology to estimate the cost efficiency of enterprises, becoming a reliable tool in revision of tariffs.

The study collected data on the banks of ANEEL - Brazilian Electricity Regulatory Agency - and other sources, about the costs and technical information of the transmission companies operating in the market from January 1998 to August 2005. Among the explanatory variables are: average wage (X_1), interest expense on line extension (X_2), population density (X_3), line extension (X_4) and in function of inefficiency, the following factors: benefits for personnel cost (Z_1), line extension of the company on total length of lines (Z_2) and catchment area (Z_3).

The transmission companies analyzed in this research were:

Empresa Amazonense de Transmissão de Energia; Empresa Paranaense de Transmissão de Energia; Empresa Regional de Transmissão de Energia; Inabensa Brasil LTDA; Empresa de Transmissão de Energia do Oeste; Expansion Transmissão de Energia Elétrica; Cachoeira Paulista Transmissora de Energia; Empresa Catarinense de Transmissão de Energia; Sul Transmissora de Energia; Transmissora Nordeste Sudeste; and Novatrans Energia.

We carried out estimations with the dependent variable in the form of total cost, according to the equations presented below:

$$\begin{aligned} \text{Log}C_r &= \beta_0 + (\beta_1 \log X_1) + \beta_2 X_2 + (\beta_3 \log X_3) + \beta_i X_i + v_i + u_i \\ m &= \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_i Z_i \end{aligned}$$

These equations are Cobb-Douglas functions, where the values of the β 's represent the elasticities with respect to total cost. The equation of the second block, which depicts the effects of inefficiency is returned as the value of m defined as the average of errors arising from the inefficiency.

Tannuri - Pianto, Arcoverde and Sousa (2009) also used the method of stochastic efficiency frontier to analyze 22 distribution companies in the Brazilian electric sector. Among the data analyzed by these researchers, are: operating cost, number of employees, volume of energy supplied, and some qualitative indicators such as the percentage of energy losses, the average duration of supply interruption per consumer per year in hours (DEC) and the average number of supply interruptions per consumer per year (FEC). They also considered some socioeconomic indicators. The information used to estimate production frontiers were drawn from the notebooks of the Infrastructure Economic Development Bank (BNDES), in the period 1993-2001. In summary, the research was based on the definition of the boundaries of production and cost estimation and its SFA (Stochastic Frontier Analysis).

Tannuri Pianto - and their partners consider the stochastic frontier model of cost efficiency with the following specification:

$$\begin{aligned} \ln C_{it} &= \beta_0 + \beta_1 \ln sal_{it} + \beta_2 \ln custo_energ_{it} + \beta_3 \ln vol_energ_{it} + \beta_{11} (\ln sal_{it})^2 + \\ &\quad \beta_{22} (\ln custo_energ_{it})^2 + \beta_{33} (\ln vol_energ_{it})^2 + \beta_{12} \ln(sal_{it}) \ln(custo_energ_{it}) + \\ &\quad \beta_{13} \ln(sal_{it}) \ln(vol_energ_{it}) + \beta_{23} \ln(custo_energ_{it}) \ln(vol_energ_{it}) + \beta_{1t} \ln(sal_{it}).t + \\ &\quad \beta_{2t} \ln(custo_energ_{it}).t + \beta_{3t} \ln(vol_energ_{it}).t + \beta_t .t + \beta_{tt} .t^2 + v_{it} - u_{it} \end{aligned}$$

e

$$\mu_{it} = \delta_0 + \delta_1 mista_{it} + \delta_2 share_{it} + \delta_3 privat_{it} + \delta_4 denscon$$

Where i indicates the observation of the i -th firm in the sample, t indicates the t -th period; C_{it} is the average operating cost; sal_{it} is the average wage; $custo_energ_{it}$ is the cost of purchased power; vol_energ_{it} is the volume of energy supplied (in MWH); $denscon_{it}$ is the density of consumers and v_{it} are assumed to be iid variables with distribution $N(0, \sigma_v^2)$ independent of u_{it} 's. The u_{it} 's are non-negative techniques inefficiencies distributed independently such that u_{it} is obtained by truncating in zero of distribution $N(\mu_{it}, \sigma_u^2)$, where the average is defined as an explicit function of specific variables vector Company, as specified.

In the present study, we used an adapted this model, where the average salary was calculated as the product of the cost of personnel and due to the volume of energy supplied by the number of employees, and the amount of energy supplied was calculated by adding the variable supply and distribution of energy. The values of the operating cost of the average wage and the cost of purchased power, were transformed into values in 2000, using as deflator the General Price Index – Internal Availability (IGP-DI) of Fundação Getúlio Vargas (FGV), extracted from the Journal Economic Environment (2002). In inefficiency function u_{it} were tested DEC, FEC and productivity variables.

Partial table with the data and its developments regarding translog function used are below, where 1, 2 and 3 represent the years 1998, 1999 and 2000, respectively, y is the average operating cost, $x1$ is the average salary, $x2$ is the cost of purchased power, $x3$ is the volume of energy supplied; $z1$ is the DEC; $z2$ is the FEC, and $z3$ is productivity (PROD).

Enterprise	Year	ln y	ln x1	ln x2	ln x3	(ln x1)^2	(ln x2)^2	(ln x3)^2	ln x1 . ln x2	ln x1 . ln x3	ln x2 . ln x3	z1=DEC	z2=FEC	z3=PROD
1	1	4,54	10,39	4,07	15,66	107,94	16,57	245,37	42,29	162,74	63,77	17,53	19,98	6780
2	1	4,69	11,21	3,92	15,05	125,77	15,34	226,60	43,92	168,82	58,95	17,7	21,09	2468
3	1	4,60	10,91	3,90	16,20	119,10	15,19	262,31	42,54	176,75	63,13	30,86	19,1	2407
1	2	4,49	11,38	3,95	15,74	129,61	15,63	247,70	45,00	179,18	62,22	18,26	17,11	9529
2	2	4,68	11,08	3,92	15,10	122,81	15,33	228,12	43,40	167,38	59,14	15,2	16,48	2708
3	2	4,52	10,87	3,95	16,25	118,09	15,59	263,93	42,91	176,54	64,15	25,38	17,09	2498
1	3	4,40	10,59	4,02	15,82	112,20	16,15	250,13	42,57	167,53	63,56	24,46	18,6	9330
2	3	4,63	11,10	3,85	15,18	123,19	14,80	230,50	42,70	168,51	58,41	14,4	14,35	2988
3	3	4,48	10,76	3,96	16,32	115,70	15,68	266,25	42,59	175,51	64,61	21,95	17,9	2709

3. Application

The process carried out with the Frontier software version 4.1 (Coelli, 1996), after several iterations involving different combinations of variables, converged to the best result, which is shown below.

the final MLE estimates are :

	coefficient	standard-error	t-ratio
beta 0	0.64587603E+02	0.64624683E+01	0.99942623E+01
beta 1	-0.57994181E+01	0.84613477E+00	-0.68540123E+01
beta 2	-0.71199227E+01	0.12400963E+01	-0.57414273E+01
beta 3	-0.20833610E+01	0.48784714E+00	-0.42705201E+01
beta 4	0.27122791E+00	0.33333859E-01	0.81367091E+01
beta 5	0.50933801E+00	0.13532011E+00	0.37639492E+01
delta 0	0.51554016E+00	0.15394315E+00	0.33488996E+01
delta 1	-0.54597682E-02	0.32130295E-02	-0.16992586E+01
delta 2	0.53390517E-02	0.26179133E-02	0.20394303E+01
delta 3	-0.87960621E-04	0.47373376E-04	-0.18567522E+01
sigma-squared	0.44447727E-02	0.94988078E-03	0.46792953E+01
gamma	0.98432517E+00	0.27986126E+00	0.35171899E+01

The equations constructed with the estimated coefficients above are:

$$y = \text{antilog } 64,588^{(0,01)} .x1^{-5,8^{(0,01)}} .x2^{-7,12^{(0,01)}} .x3^{-2,083^{(0,01)}} .x1^{2,0271^{(0,01)}} .(x2 .x3)^{0,509^{(0,01)}}$$

and

$$U_i = 0,515^{(0,01)} - 0,00546^{(0,05)} .DEC + 0,00534^{(0,01)} .FEC - 0,000088^{(0,05)} .PROD$$

with total residual variance range and equal respectively to

$$\sigma^2 = 0,00444^{(0,01)} ; e \quad \gamma = 0,984^{(0,01)}$$

where the numbers in parentheses are the corresponding levels of the Student's t distribution significance.

It is noted that the main operating cost of equation (y) all coefficients are statistically significant at 1%.

In inefficiency equation (U_i), the coefficients are statistically significant at 1%, with the exception of accompanying DEC and PROD variables, whose statistical significance is also quite acceptable, the level of 5%.

The statistical significance of the overall residual variance and range (sealer degree of stochasticity) are excellent - both at levels of 1%.

Finally, it is noted that all signs of the coefficients are in agreement with expectations.

In turn, the efficiency indices for each distribution in each year studied, are as follows:

DISTRIBUTORS	YEAR	SCORE
AES	1998	1,07E+00
CEB	1998	1,28E+00
CELESC	1998	1,41E+00
CELG	1998	1,45E+00
CELPE	1998	1,23E+00
CEMAT	1998	1,55E+00
CERJ	1998	1,06E+00
ENERSUL	1998	1,28E+00
ESCELSA	1998	1,12E+00
LIGHT	1998	1,30E+00
RGE	1998	1,18E+00
AES	1999	1,01E+00
CEB	1999	1,32E+00
CELESC	1999	1,23E+00
CELG	1999	1,29E+00
CELPE	1999	1,24E+00
CEMAT	1999	1,59E+00
CERJ	1999	1,14E+00
ENERSUL	1999	1,40E+00
ESCELSA	1999	1,19E+00
LIGHT	1999	1,12E+00
RGE	1999	1,17E+00
AES	2000	1,01E+00
CEB	2000	1,32E+00
CELESC	2000	1,19E+00
CELG	2000	1,46E+00

DISTRIBUTORS	YEAR	SCORE
CELPE	2000	1,40E+00
CEMAT	2000	1,61E+00
CERJ	2000	1,22E+00
ENERSUL	2000	1,33E+00
ESCELSA	2000	1,01E+00
LIGHT	2000	1,13E+00
RGE	2000	1,28E+00

4. Conclusion

Among the main results shown by analysis of ships in the research model, it appears that the variations of the average wage, the cost of purchased power, the volume of energy supplied and the product of these two variables explain a high degree of significance changes occurred in the middle operating costs of the distributors sampled in the years of 1998, 1999 and 2000.

Regarding the inefficiency equation, it is observed that the evolution of DEC has caused lowering effects in the indices of technical efficiency of the operating cost. Already, the effects of DEC and productivity were beneficial for improving the degree of technical efficiency of the operating cost.

For purposes of measures and actions aimed at improving cost efficiency, distributors must primarily target these variables and use the estimated indices (listed at the end of the previous section) to effect comparisons with the performance of others.

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