ADJUSTING NON PARAMETRIC EFFICIENCY SCORES FOR ENVIRONMENTAL CONDITIONS: THE CASE OF BRAZILIAN ELECTRICITY TRANSMISSION UTILITIES

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Recently, Sampaio de Sousa and Serrato (2009) proposed a multi-product, multi-input regulatory DEA cost-based framework to assess the performance of firms operating in this electricity transmission segment during the period 2004-2007, in Brazil. However, this study considers that all the inefficiency comes only from controllable factors and informational rents generated by asymmetric information between the regulator and the electric utilities. Yet, in the electricity transmission sector, many factors are outside the control of utilities such as ownership, network characteristics of the area as well as idiosyncratic shocks to some specific utility, which are seldom controlled for when computing efficiency. Hence, the use of efficiency measures based only on controllable outputs and inputs may distort the observed performance of a given utility and lead to unreliable results. There are different ways to consider environmental factors in a non-parametric framework. We can, for instance, introduce them directly as constraints in the DEA linear program. The main shortcoming of this approach comes from the fact that due to the so called curse of dimensionality, for a fixed number of observations, the use of a multitude of parameters tends to overstate the efficiency of the observations. The second practice is to use a two-stage approach. In the first stage one computes DEA measures while treating all the inputs as controllable and then, in the second stage, regresses the 'gross' computed efficiency scores on exogenous factors in order to get a "pure" measure of technical efficiency. The three stage model used here goes further and permits to distinguish among managerial inefficiency statistical noise and environment effects and hence may produce more accurate estimates of the utilities performances.

METHODOLOGY: THE MIXED DEA-SFA APPROACH

The methodology proposed by Fried et. al (2002) is a three stage approach. In the first stage, we compute DEA efficiency score, θ, as

min θ

$$\text{subject to } \theta x_i \geq X\lambda \qquad [1]$$
$$\lambda Y \geq y_i$$
$$\lambda \geq 0$$
$$\lambda e^T = 1$$

where x_i is the i-the DMU non-negative vectors of input; y_i is the i-the DMU non-negative output vector; $X = [X_1,\ldots,X_I]$ and $Y = [Y_1,\ldots Y_I]$ are, respectively, the input and output matrix in the comparison set and ; $\lambda = [\lambda_1,\ldots \lambda_I]$ represents the vector of intensity variables; $e = [1,\ldots I]$ is a unit vector. The model is solved, for each observation, to generate optimal values for θ andλ. The value of θ is the efficiency degree in inputs associated with the observation i and is comprised between 0 and 1. Hence, its optimal value allows us to compute the radial and non-radial slacks for each input as:

$$s_{ni} = x_{ni} - X_{ni}\lambda_i \qquad n = 1,\ldots, N \text{ and } i = 1, \ldots, I. \qquad [2]$$

Here, as we have a limited number of firms and data is available only from 2004, the restricted size of the data base lead to the well known *curse of the dimensionality*. This limited information reduces the discriminatory power of the usual DEA calculations. For that reason we used instead an extension of the DEA techniques, the M-DEA methodology [4].

In the second stage, we estimate N stochastic frontiers equation in which the dependent variables are the slacks computed by [2] and the explaining variables are the exogenous variables:

$$s_{ni} = f^n (z_i, \beta^n) + v_{ni} + u_{ni} \qquad [3]$$

$z_i = [z_{1i},..., z_{ki}]$ is a vector of K environmental variables; β^n is an unknown parameter vector to be estimated; the composite error term is given by $v_{ni} + u_{ni}$. The component $v_{ni} \sim (0,\sigma^2_{vn})$ stands for the statistical noise and $u_{ni} \sim (\mu^n,\sigma^2_{un})$ is the pure managerial inefficiency. Given the estimates for β^n and v_{ni}, we can compute the adjusted input quantities, x^A_{ni} as

$$x^A_{ni} = x_{ni} + [max_i\{z_i \hat{\beta}^n\} - z_i \hat{\beta}^n] + [max_i\{\hat{v}_{ni}\} - \hat{v}_{ni}] \qquad [4]$$

The first term in the square brackets says that all firms are compelled to operate in the most unfavorable environment observed in the sample; the second one states that firms must perform at the unluckiest conditions. By including those terms, we put all the DMUs in the same position concerning noise and exogenous factors. The inputs of those DMUs that have enjoyed an advantage by their relatively favorable operating environments are adjusted upwards, thus lowering their adjusted efficiency scores.

RESULTS

In the first stage we computed sequential DEA efficiency scores for 17 utilities during the period 2004-2009. Then, we used efficiency scores to compute the slacks for the four inputs used. In the second stage, we estimated, for each input, a stochastic frontier model to account for environmental factors affecting the slacks. Transmission network characteristics includes proportion of low (<138KV) and high voltage(> 440Kv) lines, number of type lines, size, population density, and asset age. We use the estimated parameters to adjust input levels according to equation [4]. The final step uses the new input levels to compute adjusted DEA efficiency scores. Let us first notice that, except for the financial costs slack equation, the LR test and the significant γ parameter indicate that modeling input slacks by using a stochastic frontier is an appropriated approach. Secondly, discretionary factors play a small, but significant role, in explaining input inefficiency in transmissions firms. However most of the inefficiency seems to be created by difference in managerial skills as shown by the higher values for γ. Negative and significant values for the parameter η indicate that managerial inefficiency is increasing during the period analyzed thus pointing out to a greater waste of inputs over the relevant period.

Our results show that, as expected, utilities which have a high proportion of their lines concentrated in low voltage lines (138KV) tend to use inputs beyond the optimal level; except for the financial input, the coefficient for this variable are positive and significant in all equations; the opposite occurs when the utilities have a high proportion of high voltage lines. Additionally, as previously stated, the concentration existing in transmission electricity industry, with a few utilities detaining a significant share of the market concentration (only three firms, Cteep, Chesf and Eletronorte collect almost 50% of the net operational revenues (NOR)), has a negative and significant impact on excess costs, particularly, for controllable costs. Hence, bigger firms translate their higher market share in a more efficient input use. Corroborating previous works *population density* do not influence input slacks. This result probably indicates that the positive congestion effect captured by this variable is being compensated by its negative scale effect. We expected that older assets, by increasing maintenance costs, would lead to higher costs. Surprisingly, older assets reduce excess costs, but the coefficient attached to this variable is significant only for the substations slack function. Firms operating in a large area are more prone to inefficiency in resource use as attested by the positive and significant coefficient for the variable *area*. Finally having many different types of lines do not affect the inefficiency in input use.

In the third stage, we re-estimated the DEA scores by using the adjusted data according to equation (4). Notice firstly that, as expected, mean efficiency increases when we consider the factors of exogenous nature. Moreover, there are significant changes in ranks, when we compare the original and DEA adjusted efficiency scores. Indeed, Spearman's rank correlation between these two efficiency measures is 0.42 attesting divergences between those ranks. Hence, ignoring exogenous variables distort the measurement of managerial efficiency for the Brazilian transmissions utilities.

When results are grouped by the utility size, measured by the net operational revenue (NOR), we realize that a significant part of the efficiency of the largest utilities comes from environmental factors and lucky conditions. By purging the efficiency scores from those elements lead to a significant reduction in their efficiency scores. Hence, a non negligible part of their efficiency is due to external conditions and cannot be attributed to better management practices. The most remarkable case is CTEEP. This utility, that present the highest first stage score, after adjusting for environmental factors, becomes one of the most inefficient utilities. This company operates within a relatively small area in the richest and more dynamic Brazilian State (São Paulo). Its numerous lines are concentrated in a relatively small area, thus allowing this utility to exploit the economies of scale that characterize the electricity transmission sector. On the opposite direction stand the smaller and mid-size companies. When we re-evaluate their performance, by considering their unfavourable extenuating circumstances, they show a substantial improvement. The case of TSN illustrates this point. This utility suffers from many disabilities. It operates in a large area and its lines are disposed as a straight line, linking the center west to the northeast (not as grid like CTEEP). Second, as TSN is a mid-size utility its gains of scale are limited, even if this company has incorporated small concessions without a proportional cost increase. The fact that TSN has no low voltage lines is not sufficient to counterbalance the impact of their unfavourable exogenous conditions. Hence, once we adjust its efficiency scores, this utility present a remarkable improvement in efficiency.

CONCLUSIONS

We used a DEA-SFA mixed approach that accounts for non controllable elements to assess the efficiency of the electricity transmission utilities in Brazil. Our results show that mean efficiency increases when we consider the factors of exogenous nature. Moreover, when we compare the original and DEA adjusted efficiency scores we found significant changes in ranks of those two efficiency measures. Hence, ignoring exogenous variables distort the measurement of managerial efficiency for the Brazilian transmissions utilities. Our findings suggested that size of the utilities do matter for efficiency. Due to increasing returns in the electricity transmission markets favor large utilities. Hence, the relatively low efficiency scores, in the first stage, shown by small and mid-size companies reflect those exogenous and lucky factors rather than managerial performance. When we level the playing field for those firms, they experiment a significant improvement in their efficiency scores.

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