



Universidade de Brasília
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Série Textos para Discussão

**Technical Efficiency of the Brazilian Municipalities:
Correcting Non-Parametric Frontier Measurements for
Outliers**

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TECHNICAL EFFICIENCY OF THE BRAZILIAN MUNICIPALITIES: CORRECTING NON-PARAMETRIC FRONTIER MEASUREMENTS FOR OUTLIERS

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ABSTRACT

In this paper we estimate the DEA technical efficiency for 4796 Brazilian municipalities, by applying a recently proposed method, which combines Bootstrap and Jackknife resampling techniques to eliminate the effect of outliers and possible errors in the data set. First, an algorithm implementing Jackknife is used to extract leverage of all data points, that is, the impact of removal of the observed municipality on DEA calculations performed on the rest of the data set. Next, Bootstrap stochastic resampling is implemented, taking into account leverage information. We perform calculations applying different distribution functions to identify and eliminate high leverage municipalities, using both constant and variable returns to scale DEA method. It is demonstrated that this approach proves robust to presence of outliers and/or errors in the data set, and we believe the resulting analysis to be adequate for use in the decision making process for resource allocation.

KEYWORDS

Data Envelopment Analysis, Outliers Detection, Leverage

1. Introduction

A major economic problem, in many countries all over the world, is how to allocate usually scarce government resources in such a way as to provide public services in the most efficient manner. In a large political federation such as Brazil, the critical issue becomes the choice of the degree of decentralization in the provision of those services. Currently, there seems to be a broad consensus that such decentralization is substantially advantageous for the implementation and distribution of public services. Various reasons are given for why local governments should have an advantage in providing such services. First, the proximity of users may help to identify the priorities of the community, second, the decentralization of resources, by simplifying the bureaucratic

channels before the funds reach their destination, reduces the opportunities for corruption and inefficiencies, and finally, requirements of managerial capacity are lower, which is essential for the good performance of projects in small and medium sized municipalities.

However, the mere decentralization of public spending does not guarantee, *per se*, a satisfactory provision of the corresponding services. It is also necessary to ensure that public funds are used in the best possible way by the municipalities. Therefore, it is imperative to establish efficiency criteria that could be used to evaluate how public resources are being spent by local governments. In an attempt to establish such criteria, in this work we estimate cost-efficiency frontiers for the Brazilian municipalities by using non-parametric methods.

Non-parametric efficiency measurement methods such as Data Envelopment Analysis (DEA) [1-4] and Free Disposal Hull (FDH) [5-7] have been widely applied in different contexts including the computation of cost-efficient frontiers for local governments [7-9]. The enormous popularity of those methods comes from their flexibility, as they impose no a priori functional forms on the technology. In fact, they require only that the production set fulfill such properties as free disposal, convexity, and piece-wise linearity of the technology.

Yet, those measurements may be seriously affected by the presence of *outliers*, that is, super-efficient observations, as well as data errors, that substantially underestimate the overall efficiency scores. More precisely, as these methods are based on the (extreme) concept of frontier composed of a relatively small number of observations, a single observation far removed from the average may itself push the frontier, and therefore artificially increase the efficiency requirements for the whole data set. Therefore, in order to assure credibility of the efficiency indices, it is crucial to implement some additional method to correct for such discrepancies. Only then one may hope to obtain truly representative estimators, which could be useful for the decision making process. This problem becomes particularly hard to solve when the data set is both huge and diverse, as is the case of the Brazilian municipalities. In such a case, the size and heterogeneity of the data set makes it virtually impossible to manually detect the outliers and/or errors, thus requiring use of some systematic and automatic approach.

In this paper we estimate the DEA technical efficiency for 4796 Brazilian municipalities, by applying the method recently proposed by Stosic and Sampaio de Sousa [10], which combines Bootstrap and Jackknife resampling techniques to eliminate the effect of outliers and possible errors in the data set. In section 2 we briefly describe the DEA method, and the above-mentioned approach for outlier detection. In section 3 we describe the chosen input and output variables, and section 4 presents the obtained results. Finally, in section 5 we draw the conclusions.

2. Robust DEA measurements

Non-parametric deterministic approaches to efficiency measurement, such as DEA, are characterized by the use of weak assumptions concerning the reference technology. Except for the usual regularity axioms such as the bounded-ness and closed-ness of the technology, those methods rely on simple hypothesis such as convexity and free disposability in inputs and outputs. However, as already mentioned, one of the shortcomings of this approach is its high sensitivity to the presence of outliers and errors in the data. Below we briefly describe the DEA method, and the approach adopted for making DEA estimates more robust.

2.1 Data Envelopment Analysis

For each decision making unit (DMU), the technology transforms nonnegative inputs $\mathbf{x}^k = (x_{k1}, \dots, x_{kN}) \in \mathcal{R}_+^N$ into the nonnegative outputs $\mathbf{y}^k = (y_{k1}, \dots, y_{kM}) \in \mathcal{R}_+^M$. For input-based measures of technical efficiency the technology is represented by its production possibility set $T = \{ (x,y): x \text{ can produce } y \}$, the set of all feasible input-output vectors. Technical efficiency for the municipality k may be computed as the solution of the following linear program:

$$\theta_k = \min(\theta)$$

subject to:

$$\begin{aligned} \theta x_{kn} &\geq \sum_{j=1}^K z_{kj} x_{jn} & n = 1, \dots, N \\ y_{km} &\leq \sum_{j=1}^K z_{kj} y_{jm} & m = 1, \dots, M \\ \theta, z_{kj} &\geq 0 & k = 1, \dots, K \end{aligned} \quad (2.1)$$

This version of the DEA methodology implies strong restrictions concerning the production set, in particular constant returns to scale. These hypotheses can be easily relaxed by modifying the restrictions on the intensity vector \mathbf{z} . For example, Färe, Grosskopf and Lovell [3,4] have extended this technique to include the existence of non-increasing returns to scale by adding to (2.1) the following restriction:

$$\sum_{j=1}^K z_{kj} \leq 1 \quad k = 1, \dots, K \quad (2.2)$$

Here, the sum of the intensity variables cannot exceed unity, implying that the different activities can be contracted but cannot be expanded to infinity. In the case of variable returns to scale - the BCC - Banker, Charnes and Cooper [5] model - activities cannot be expanded radially without limits, nor contracted to the origin. The feasible set of activities is formed by all convex combinations of observed activities, located on the boundary of the productive set. We have, thus, increasing returns for low levels of production and decreasing returns for higher levels. It is well known that the efficiency indices associated with this technology - henceforth denominated DEA-V - are obtained by imposing equality on restriction (2.2).

2.2 Leverage and “Jackstrap” procedure

Due to extreme sensitivity of DEA measurements to the presence of *outliers* some additional procedure is required in order to make DEA estimates more robust. Various approaches have already been proposed in the literature to cope with this type of situation [11-14]. Some of these proposals [11-12] however, depend on manual inspection of data, which is virtually impossible for large data sets, as is the current case of Brazilian Municipalities. In this paper, we apply the recently

proposed method [10] of combined Bootstrap and Jackknife resampling for automatic detection of outliers. The method is based on calculating the leverage of each DMU, that is, the effect produced on the outcome of DEA efficiencies of the other DMUs, when the observed DMU is removed from the data set. The leverage information may then be used to detect and automatically eliminate outliers and errors in the data set. The basic idea is that outliers, and DMU's with errors in data, are expected to show higher leverage than the global mean, and should be selected with smaller probability than the others. In what follows we briefly describe the adopted procedure.

One direct way to define the leverage [10] for each DMU is to perform Jackknife resampling technique as follows. First, one applies DEA for each of the DMUs using the unaltered original data set, to obtain the set of efficiencies $\{\theta_k | k = 1, \dots, K\}$. Then, one proceeds successively removing one by one DMU, each time recalculating the set of efficiencies $\{\theta_{kj}^* | k = 1, \dots, K; k \neq j\}$, where index $j = 1, \dots, K$ represents the removed DMU. The leverage of j-th DMU may then be defined as standard deviation

$$\ell_j = \sqrt{\frac{\sum_{k=1, k \neq j}^K (\theta_{kj}^* - \theta_k)^2}{K - 1}} \quad (2.3)$$

It turns out that this direct approach is highly computationally intensive, and may be unfeasible on huge data sets with the available computer resources (in the current case of roughly 5000 DMUs one sequence of DEA runs takes roughly 1h on a 1Ghz Pentium III, running all sequences would require more than seven months of continuous CPU time). For this reason, we apply a more efficient stochastic procedure, which combines Bootstrap resampling with the above Jackknife scheme as follows:

1. One selects randomly a subset of L DMUs (typically 10% of K) and performs the above procedure to obtain subset leverages $\tilde{\ell}_{j_l}$, where index j takes on L different values from the set $\{1, \dots, K\}$.

2. Repeat the above step B times, accumulating the subset leverage information $\tilde{\ell}_{jb}$ for all randomly selected DMUs (for B large enough, each DMU should be selected roughly $n_j \approx BL/K$ times).
3. Calculate mean leverage for each DMU as

$$\tilde{\ell}_j = \frac{\sum_{b=1}^{n_j} \tilde{\ell}_{jb}}{n_j}$$

and global mean leverage as

$$\tilde{\ell} = \frac{\sum_{j=1}^K \tilde{\ell}_j}{K}$$

This leverage information may now be used in different ways to detect and eliminate outliers and errors in the data set. To eliminate DMUs with high leverage values we have tested several probability distribution functions, that is, linear, inverse, exponential, and the Heaviside step function. The linear probability distribution is given by

$$P(\tilde{\ell}_k) = \frac{\ell_{\max} - \tilde{\ell}_k}{\ell_{\max} - \ell_{\min}} \quad (2.4)$$

where ℓ_{\max} and ℓ_{\min} are the maximum and the minimum leverage of the set $\{\tilde{\ell}_k ; k = 1, \dots, K\}$, respectively. The probability of retaining a DMU with leverage ℓ_{\min} is therefore unity, while probability of retaining a DMU with leverage ℓ_{\max} is zero. The inverse probability distribution may be represented by

$$P(\tilde{\ell}_k) = \left(\frac{\ell_0}{\tilde{\ell}_k} \right) \left(\frac{\ell_{\max} - \tilde{\ell}_k}{\ell_{\max} - \ell_0} \right) \quad (2.5)$$

where ℓ_0 is now the lower bound for $\tilde{\ell}_k$ (threshold value below which DMU's are retained with probability one). The exponential distribution is

$$P(\tilde{\ell}_k) = \frac{e^{-\tilde{\ell}_k} - e^{-\ell_{\max}}}{e^{-\ell_{\min}} - e^{-\ell_{\max}}}, \quad (2.6)$$

and finally, the Heaviside step function is given by

$$P(\tilde{\ell}_k) = \begin{cases} 1 & , \quad \tilde{\ell}_k \leq \tilde{\ell} \log K \\ 0 & , \quad \tilde{\ell}_k > \tilde{\ell} \log K \end{cases} \quad (2.7)$$

where in order to take into account the sample size K , the threshold level was chosen as the product of global leverage $\tilde{\ell}$ and $\log K$. Application of the above procedure makes DEA more reliable, as will be shown in some detail in section 4 in the case of Brazilian Municipality data.

3. Data

The implementation of the above outlined methodologies requires information about aggregate total costs and other relevant inputs, as well as the amount of public services available to the population for the municipalities (outputs). Initially, information for the 5264 Brazilian municipalities was collected. We excluded data for municipalities for which some key information was missing. This way 620 communes were dropped since 493 of them had a recorded population of zero and 127 others had no data on current expenditure.¹ The final data set was composed of 4796 municipalities.

¹ The reason why this happens lies on the flourishing creation of new municipalities in Brazil. Indeed, some municipalities, although legally created, have not yet being dismembered from the mother-commune. As a result, they do not report output indicators. In addition, null values for current expenses may be also explained by the fact that the data have not yet been reported by the STN (National Treasure Secretary).

3.1 Input and output indicators for the Brazilian municipalities

Aggregate total costs were computed as the value of municipal current spending. The other inputs used were the number of teachers (as a proxy for personnel inputs), the number of hospital and health centers, as they are the main providers of health services. The rate of infant mortality stands as an input because if health services are efficient, this indicator should be as low as possible. As for output measures, due to the impossibility of quantifying directly the supply of public services, they were approximated by a set of selected indicators, which are observable factors taken as proxies for the services supplied. After a careful choice, nine output indicators were retained. A list of inputs and outputs are provided in Table 3.1, together with their respective sources, and the public service they are supposed to represent.

Table 3.1 - Input and Output Indicators and the Corresponding Municipal Services – 2001

<i>Input and Output Indicators</i>	<i>Source</i>	<i>Municipal Services of which indicators serve as proxies</i>
<i>- Input Indicators</i>		
1. Current spending	STN ¹	Aggregate total costs
2. Number of teachers	Censo Escolar/MEC	Personnel input
3. Rate of infant mortality	IBGE ²	Public health services
4. Hospital and health services	IBGE	Public health services
<i>- Output Indicators</i>		
1. Total resident population	IBGE	Administrative services
2. Literate population	MEC ³	Educational services
3. Enrollment ⁴ per school	Censo Escolar/MEC	Educational services
4. Student attendance per school	Censo Escolar/MEC	Educational services
5. Students approved per school	Censo Escolar/MEC	Educational services
6. Students in the right class per school	Censo Escolar/MEC	Educational services
7. Households with access to safe water	IBGE	Health and housing conditions
8. Households with access to sewage system	IBGE	Health and housing conditions
9. Households with access to garbage collection	IBGE	Health and housing conditions
Sources: 1: STN - Secretaria do Tesouro Nacional (National Treasure Secretariat); 2: IBGE - Instituto Brasileiro de Estatística, Censo Demográfico de 1991; 3: MEC - Ministério da Educação; 4: All data refer to primary and secondary municipal schools.		

4. Results

In this section we present the results of application of the “Jackstrap” procedure described in section 2, to the data discussed in section 3. We first discuss leverage results, then we present outlier detection by using different probability functions, and finally we show robust DEA efficiency calculations.

4.1 Leverage calculations

Leverage was calculated for all of the 4796 Brazilian municipalities using both the CCR and the BCC models. Due to the size of the data set, and the fact that most of the DMUs have low leverage, only the results for the twenty municipalities with highest leverage are shown in Table 4.1.

Table 4.1 - Leverage and Leverage Hits for Selected Municipalities

Municipality	CRS			VRS		
	Leverage	Number of Hits	Total Hits	Leverage	Number of Hits	Total Hits
Santo André	0,3194	113	115	0,1846	113	115
Barra do Garças	0,1511	107	111	0,1098	107	111
Ribeirão das Neves	0,1136	99	99	0,0445	99	99
São Gonçalo	0,1048	92	92	0,0571	92	92
Nossa Senhora do Socorro	0,1000	101	105	0,0497	101	105
Palhoça	0,0980	94	97	0,0612	96	97
Ibirité	0,0929	107	108	0,0475	107	108
Paço do Lumiar	0,0902	79	81	0,0532	79	81
Alvorada	0,0887	97	101	0,0563	97	101
Santo Antônio do Sudoeste	0,0876	98	99	0,0805	99	99
Jaboatão dos Guararapes	0,0868	100	106	0,0447	99	106
Bragança	0,0840	102	104	0,0480	102	104
Nazareno	0,0778	91	91	0,0718	91	91
Nova Iguaçu	0,0775	111	120	0,0419	111	120
Quixadá	0,0760	90	93	0,0477	90	93
São João de Meriti	0,0749	110	112	0,0405	109	112
São Cristóvão	0,0743	83	91	0,0433	84	91
Propriá	0,0743	105	112	0,0385	104	112
Francisco Morato	0,0739	86	90	0,0270	86	90
São José de Ribamar	0,0703	109	113	0,0458	109	113
Viamão	0,0697	85	92	0,0452	87	92
Aparecida de Goiânia	0,0676	105	111	0,0333	105	111

The second column lists the obtained leverage values, while columns “Number of hits” and “Total hits” correspond to the number of times that the removal of the given municipality produced nonzero leverage, and the total number of times that the given municipality was chosen within the “Jackstrap” procedure, respectively. While all the municipalities have the same chance to be chosen for leverage testing (values in column 4 are similar for all the municipalities), the ones that present high number of leverage hits typically also have high leverage, and represent potential outliers.

Let us now briefly comment the results shown in Table 4.1. The municipalities appearing in the table tend to present serious distortion in declared input and/or output values. Some of them undoubtedly present measurement errors. The most common ones are those concerning municipal total spending, which becomes clear when we analyze per capita figures. For instance, the municipalities of Santo André, Barra dos Garças, Pontal do Araguaia, São Francisco de Itabapoana and Santo Antônio do Sudoeste total spending *per capita* are, respectively, R\$6,00, R\$0,30, R\$0,49, R\$0,31 and R\$0,32, while the average for the sample is R\$445,21. Certainly, this is a measurement error; with such low expenses they would have been unable to provide all the public services claimed by those communes. Other cities show extremely high educational output indicators, such as is the case, for example, for Ribeirão das Neves, Bebedouro and Iperó among others. Those inflated and inconsistent values explain in part the high leverage values and leverages hits found for corresponding municipalities. Just to illustrate this point, notice that the enrollment per school in Iperó, a small city of around 18000 inhabitants, reaches 2165 students, twelve times higher than the national average (171 students). So, our “Jackstrap” procedure proved to be very effective in detecting these atypical observations, thus preventing them from distorting the efficiency estimates.

As expected, leverage values are lower when we use the BCC model as the higher number of efficient municipalities produced by this variant contributes to mask the problem of *outliers*. However, as in this model the leverage results are simply scaled down with respect to the ones obtained by the CCR variant, the identification of outliers, by using the “jackstrap” method, is very similar in both models.

4.2 Outlier detection using leverage information

To demonstrate how the presence of outliers affects the overall DEA estimates, we have performed DEA calculations on the unaltered data set for 4796 Brazilian municipalities. The histogram of the obtained efficiency indices is shown in the Figure 1.

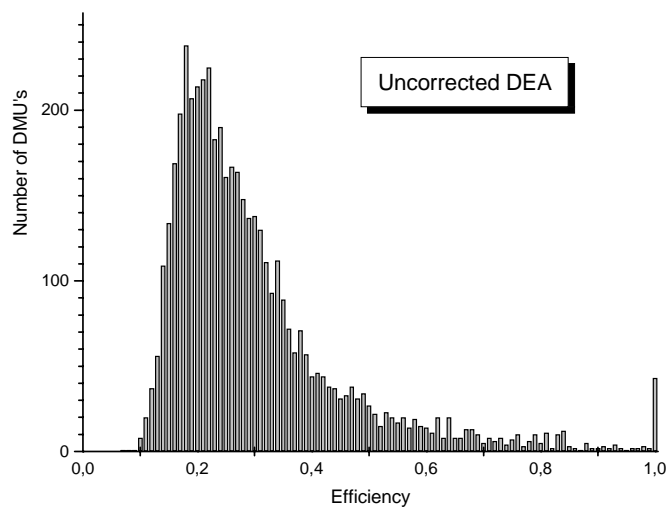


Figure 1. Histogram of DEA efficiencies for 4796 Brazilian municipalities, obtained using the original data set.

It is seen from the figure that the obtained efficiency values are shifted towards lower efficiency region, and their distribution is highly asymmetric, as may be expected in the case of presence of outliers. Therefore, these results are not reliable, and should not be used directly in the decision making process. In order to correct these results the probability distributions presented in section 2 were used to eliminate a number of municipalities with the highest leverages, using both CCR and the BCC DEA techniques, after which the corresponding DEA method was applied to the remaining set. The resulting frequency distributions are shown in Fig.2 for the CCR calculations.

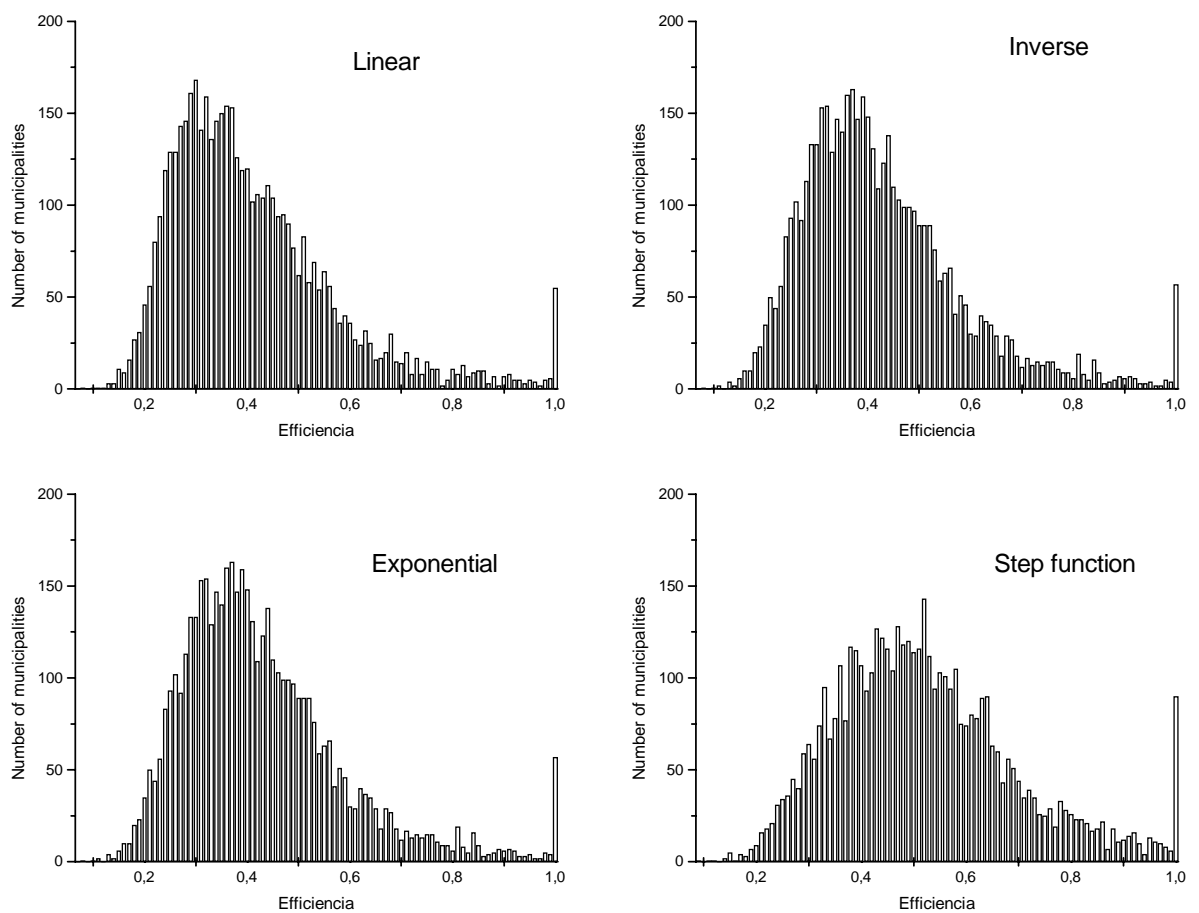


Figure 2. “Jackstrapped” DEA score histograms, obtained using different probability functions to correct for outliers (see text for more details).

From figure 2 it follows that application of different probability functions results in different effects regarding the shape of the distribution, the Heaviside step function being the most reminiscent of the normal curve.

Before proceeding with a more detailed analysis of the results, it should be pointed out that the effect of outliers, and therefore their detection and elimination, becomes increasingly important with decreasing number of input/output variables used in the DEA analysis. To demonstrate this

point, we have also performed leverage calculations on the Brazilian municipality data using a single input variable (current spending, as described in section 3.1), and discarding the other three inputs. Figure 3 shows the results of these calculations. In comparison with figure 1, which was obtained using four input variables, it is seen that the uncorrected data shows extreme distortion, majority of efficiencies being compressed within less than one percent of the full scale (notice the scale maximum of 0.01 on the first graph of Figure 3). However, using the leverage information with the Heaviside probability scheme restores the efficiency distribution to nearly Gaussian form, strongly resembling with the results of figure 2 (which was obtained using all the four input variables).

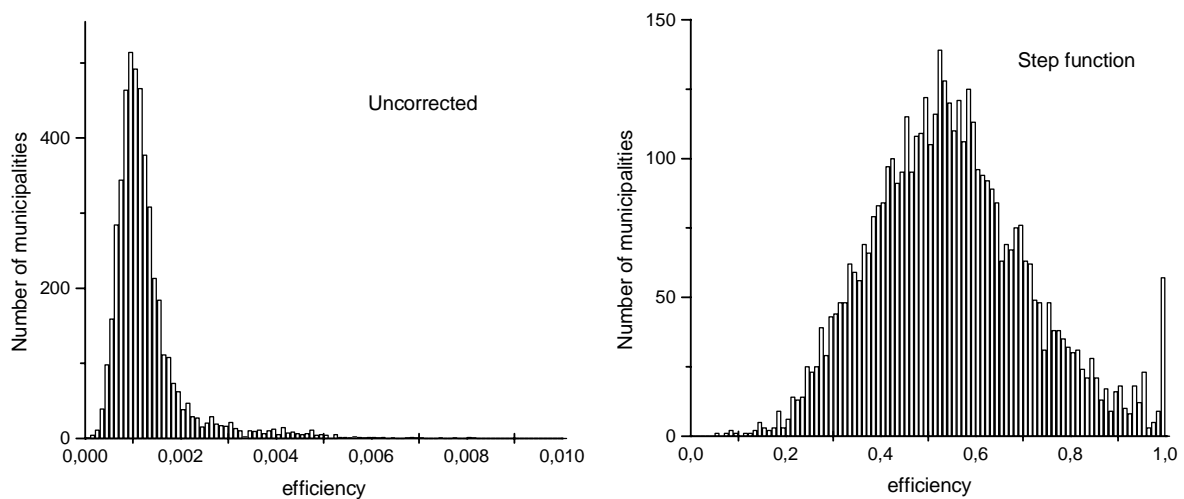


Figure 3. DEA efficiency histograms for the reduced data set (using a single input variable), before and after applying the “jackstrap” procedure with the Heaviside step function.

Returning to our analysis of results obtained using the full data set, in Tables 4.2 and 4.3 we report descriptive statistics for CCR and BCC efficiency calculations. Notice that the presence of outliers not only affects the number of efficient communes, but also substantially influences the magnitude of the computed scores, particularly when the CCR technique is used. Here, the magnitude of the efficiency scores seems to be inversely related to the leverage scheme used.

Indeed, between the uncorrected score and its equivalent using the step function, the median of the efficiency estimates almost doubles.

Skewness coefficients are also helpful in detecting the impact of outliers on efficiency measures representing quantitative measure of degree of asymmetry of the distribution. Hence, the high positive values of skewness for both DEA variants indicate that the efficiency scores are systematically higher than when high leverages observations are excluded. Observe also that the skewness as well as the kurtosis drop substantially with the step function is used, indicating that thus obtained distribution of the efficiency scores is closest to the normal distribution.

Table 4.2: Descriptive Statistics for CCR Efficiency Measures
Using Different Leverage Schemes

Leverage scheme	Number of Observations	Mean	Median	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum
Uncorrected	4796 (0) ¹	0,303	0,257	0,162	1,956	4,415	0,075	1,000
Linear	4766 (30)	0,409	0,373	0,162	1,338	2,123	0,076	1,000
Inverse	4793 (3)	0,428	0,398	0,158	1,221	1,904	0,076	1,000
Exponential	4764 (32)	0,429	0,399	0,157	1,179	1,823	0,077	1,000
Step function	4755 (41)	0,522	0,503	0,176	0,631	0,162	0,095	1,000

¹: The number in parenthesis corresponds to the municipalities removed from the data set

The BCC estimates represented in Table 4.3 are similar to those obtained by the CCR method, except when the uncorrected data are used. The fact that this method envelops the data more closely implies that a larger number of efficient municipalities – including the ones containing measurement errors in data - contribute to increase the mean and the median of the estimated scores, therefore concealing the outlier problem. However, the higher standard deviations of the BCC scores show an increased dispersion of the efficiency scores; this may be caused by erroneous or irrelevant observations, as attested by the strong variation on the kurtosis measure that may depend on only a few municipalities in the tails of the distribution.

Table 4.3: Descriptive Statistics for BCC Efficiency Measures
Using Different Leverage Schemes

Leverage scheme	Number of Observations	Mean	Median	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum
Uncorrected	4796 (0) ¹	0,545	0,517	0,184	0,613	-0,242	0,201	1,000
Linear	4766 (30)	0,410	0,373	0,163	1,339	2,109	0,076	1,000
Inverse	4793 (3)	0,404	0,368	0,161	1,341	2,175	0,076	1,000
Exponential	4764 (32)	0,404	0,369	0,160	1,319	2,131	0,076	1,000
Step function	4755 (41)	0,525	0,507	0,165	0,620	0,359	0,077	1,000
1: The number in parenthesis corresponds to the municipalities removed from the data set								

To summarize, the distributions of the DEA indexes, when outliers are included, are strongly shifted downwards. Clearly, with the proposed corrections the efficiency scores are much less vulnerable to such observations, thus making the Jackstrap method more reliable. To illustrate the robustness of the efficiency estimates obtained by using this method, we recalculated the scores by removing up to 128 highest leverage observations (potential outliers). Figure 4 presents the results for the first ten municipalities of the sample. When only Santo André is removed (the municipality with the highest leverage rate), the computed efficiency scores for those ten communes considerably increases. After removing a few more observations, the rate of increase of the scores drops substantially. Finally, this increase stabilizes when approximately sixty municipalities are removed.

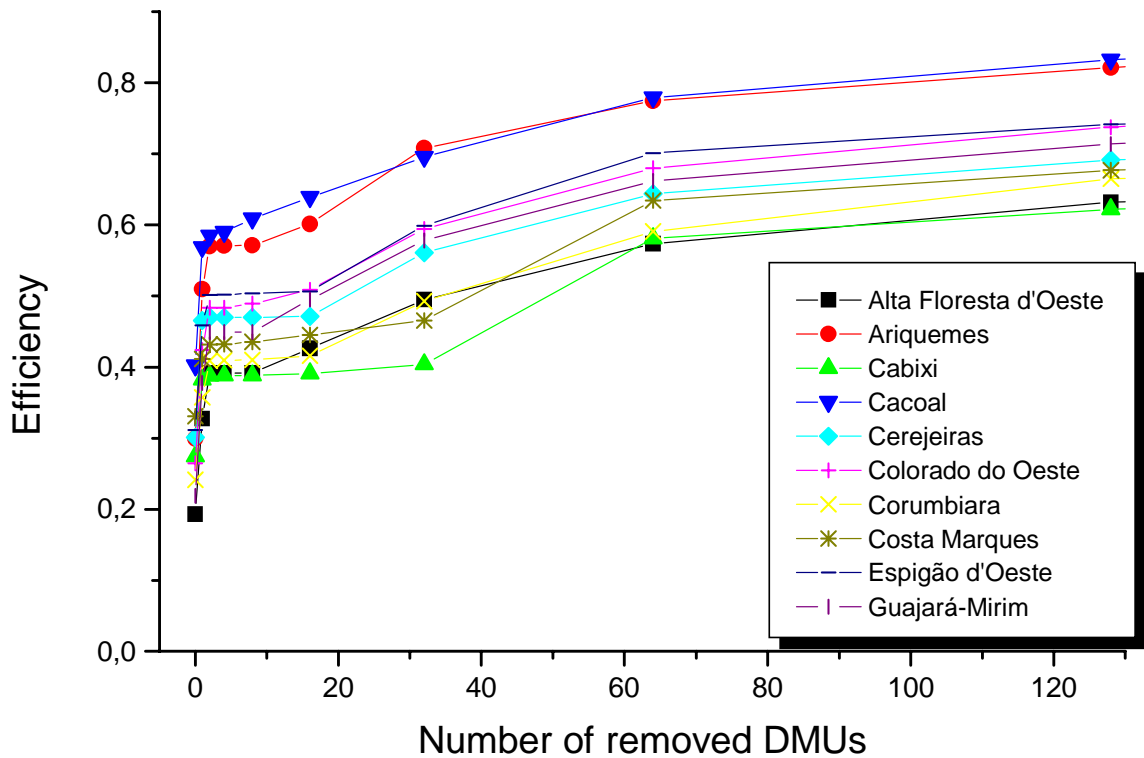


Figure 4. DEA scores for the first ten municipalities of the sample, obtained by successively removing observations with highest leverage (potential outliers).

Notice also that, by removing outliers, not only the score increases, but also the ranks of some municipalities are altered. Hence, for the whole set of municipalities, this increased robustness of the efficiency scores may be inferred by using the Spearman's rank correlation coefficient. Results of this simple non-parametric test, represented in Table 4.4, show that removing a single municipality presenting the highest leverage (Santo André) from the original data set causes more substantial ranking changes (correlation factor of 0,8625), then removing 64 municipalities from the set where the first 64 have already been removed (correlation factor of 0,9879). In fact, the numbers of municipalities progressively removed from the sample doubles between successive columns/rows shown in the table, demonstrating the exponential weakening of the effect of DMUs, with their leverage rank.

Table 4.4 – Spearman’s Rank Correlation matrix across DEA CCR efficiency scores after removing high leverages observations (N= 4668)

# Municipalities removed	0	1	2	4	8	16	32	64	128
0	1,0000	0,8625	0,7785	0,7767	0,7698	0,7573	0,6648	0,6846	0,6561
1		1,0000	0,9735	0,9982	0,9980	0,9920	0,9778	0,9855	0,9879
2			1,0000	0,9982	0,9966	0,9882	0,9751	0,9762	0,9614
4				1,0000	0,9980	0,9907	0,9760	0,9761	0,9596
8					1,0000	0,9920	0,9778	0,9855	0,9879
16						1,0000	0,9778	0,9920	0,9658
32							1,0000	0,9855	0,9715
64								1,0000	0,9879
128									1,0000

4.4 Size and efficiency scores

Table 4.5 categorizes the Brazilian municipalities into efficient and inefficient by using the Heaviside Step Function and the CCR and BCC methods. Both methodologies seem to indicate that smaller cities tend to be less efficient than larger ones.

Table 4.5: Rating of the Municipalities by Size By Using The Step Function – CCR and BCC Models

Classes of Population	Number of Municipalities	Efficient		Inefficient municipalities				Mean Efficiency All municipalities
		total	%	total	%	Mean	Std. Dev.	
CCR Model								
0 – 9999	2182	27	1,24	2155	98,76	0,43596	0,15102	0,44294
10000-19999	1252	11	0,88	1241	99,12	0,53119	0,12645	0,53531
20000-29999	507	10	1,97	497	98,03	0,57703	0,13197	0,58537
30000- 49999	357	4	1,12	353	98,88	0,63691	0,13165	0,64098
50000-99999	261	16	6,13	245	93,87	0,67019	0,15598	0,69041
100000-149999	64	3	4,69	61	95,31	0,66146	0,18354	0,67733
150000-299999	77	7	9,09	70	90,91	0,68426	0,16428	0,71296
300000-499999	29	4	13,79	25	86,21	0,69530	0,15877	0,73733
+ 500000	26	3	11,54	23	88,46	0,76901	0,14600	0,79566
BCC Model								
0 – 9999	2174	19	0,87	2155	99,13	0,44850	0,14141	0,45332
10000-19999	1253	12	0,96	1241	99,04	0,53333	0,12125	0,53780
20000-29999	507	8	19,33	499	80,67	0,56809	0,12957	0,57491
30000- 49999	357	4	1,12	353	98,88	0,62244	0,12708	0,62667
50000-99999	265	17	6,42	248	93,58	0,65847	0,15691	0,68038
100000-149999	65	4	6,15	61	93,85	0,64908	0,17872	0,67068
150000-299999	78	8	10,26	70	89,74	0,67249	0,15705	0,70608
300000-499999	29	4	13,80	25	86,20	0,68848	0,15247	0,73145
+ 500000	26	3	11,54	23	88,46	0,76737	0,14562	0,79421

Indeed, the quality of the frontier adjustment improves significantly as the size of the municipality increases, as can be seen on Figure 5 where we show the average efficiency as a function of average size. The circles represent averages calculated for all municipalities, the squares correspond only to inefficient municipalities, and the broken line connecting the individual points serves as a guide to the eye. The fact that the curves steadily increase on the semi-logarithmic scale indicates that efficiency increases roughly as the logarithm of size. Also, it is seen that the curves begin to differ roughly at population 60000 for both the CCR and BCC methods, where efficient municipalities begin to significantly affect the overall average efficiency score.

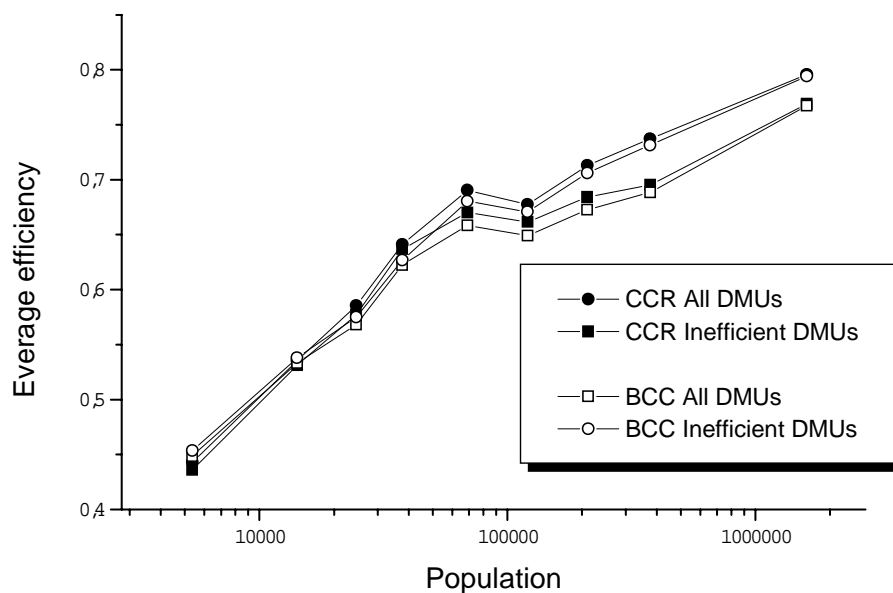


Figure 5. CCR and BCC DEA average efficiency scores as a function of municipality population, for all and only the inefficient communes.

The observed effect that the efficiency of municipalities increases with their size may be a consequence of various reasons. First, it may stem from the presence of local increasing returns to scale prevalent among small municipalities. For those communes, a given proportional increase in

all output indicators could be achieved with a proportionally inferior augmentation of inputs. Hence, it would be possible to increase the size of the typical Brazilian municipality and yet provide the required public services to these larger communes without incurring in an equivalent increase in public expenditure. Those cities are unable to exploit the economies of scale that characterizes the production of certain public services, thus, failing to use optimally its resources. In the case of educational services, there is ample evidence that operating costs decrease with enrollment due to existence of high fixed costs.² Consequently, larger schools tend to be more cost-efficient because the fixed costs are diluted among a higher number of students. This fact, clearly, discriminates against small municipalities as their schools have only a few students on average and thus tend to present excessively high average costs. Were those cities larger, they would be able to enroll a greater number of students and reduce the cost per student without significant loss of educational quality. A similar explanation applies to other local public services.²

To support this point, as a preliminary test, we calculated the returns to scale by using the method proposed in [3]. Within the DEA-C approach, the presence of local non-convexities may be computed by the value of the sum of the weights $S \equiv \sum_{j=1}^K z_{kj}$, as stated in the linear program described in Section 2, evaluated at the optimal solution. Thus, $S < 1$ implies that locally (for the observed municipality) returns to scale are increasing; $S > 1$ points out to decreasing returns; and when $S = 1$, returns are constant. Results of our calculations shown in Table 4.6 illustrate this argument, where it is seen that increasing returns are prevalent among small municipalities.³

² The existence of important fixed costs involved in the production of administrative services (e.g. the creation and maintenance of a physical and human administrative infrastructure) explains why the *per capita* cost of those services is probably higher for smaller municipalities.

Table 4.6: Returns to Scale in Brazilian Municipalities

Classes of Population	Total Municipalities #	Constant Returns		Decreasing Returns		Increasing Returns	
		#	%	#	%	#	%
0 – 9999	2182	27	1,24	4	0,18	2151	98,58
10000-19999	1252	11	0,88	11	0,88	1230	98,24
20000-29999	507	10	1,97	14	2,76	483	95,27
30000- 49999	357	4	1,12	12	3,36	341	95,52
50000-99999	261	16	6,13	11	4,21	234	89,66
100000-149999	64	3	4,69	2	3,13	59	92,19
150000-299999	77	7	9,09	1	1,30	69	89,61
300000-499999	29	4	13,79	1	3,45	24	82,76
+ 500000	26	3	11,54	4	15,38	19	73,08

Source: Our calculations

Second, the relative inefficiency of small municipalities comes from the fact that although some of them receive substantial resources from royalties on oil and water, those “over-financed” communes do not present significantly improved output indicators in comparison with the other communes, thus obtaining low efficiency scores. Table 4.7 illustrates this point, where we present results for twenty municipalities selected from the 50 most inefficient. All of those communes do not have more than 60000 inhabitants and roughly half of them receive substantial income from royalties (some of them may be considered very small municipalities for Brazilian standards). Although their *per capita* spending levels are very high, those increased costs are not translated into higher quantity and quality of public services, which explains their very low efficiency scores. This pattern is repeated for a considerable number of small and inefficient municipalities.

³ Of course, a more detailed investigation is needed to corroborate this point, including testing different methods and concepts in order to conduct a proper evaluation of the scale efficiency and returns to scale in DEA. This will be the object of further research.

Finally, as may be seen from the last column of table 4.6, low efficiency scores of some small municipalities can be explained by the fact that they engage in tourism. In such cases, higher per capita spending may be explained in part by the fact that population of those cities could be seriously underestimated, as they tend to have a significant floating population.

Table 4.7: Selected Inefficient Municipalities

Municipalities	State	Efficiency Scores	Population	Per Capita Current spending	Royalties (oil and water))	Tourism Municipalities
São Félix do Coribe	BA	0,09465	11758	3244	NO	NO
São Francisco do Conde	BA	0,11271	26282	2525	YES	NO
Quissamã	RJ	0,12222	13674	2615	YES	YES
Itacuruba	PE	0,13819	3669	1494	YES	NO
Quixaba	PB	0,14225	1308	1281	NO	NO
Paulínia	SP	0,14550	51326	3293	YES	NO
Carapebus	RJ	0,15811	8666	1711	YES	NO
Soledade de Minas	MG	0,16985	5155	2599	NO	NO
Triunfo	RS	0,17978	22166	1691	NO	YES
Campos de Júlio	MT	0,18615	2895	1488	NO	NO
Santa Helena	PR	0,21115	20491	1599	NO	YES
Sandovalina	SP	0,21506	3089	2035	YES	NO
Itaipulândia	PR	0,21893	6836	2461	NO	YES
Itatiaia	RJ	0,23322	24739	1278	YES	YES
Tapira	MG	0,24129	3327	1426	NO	NO
Rio das Ostras	RJ	0,24390	36419	1376	YES	YES
São Sebastião	SP	0,24797	58038	1345	YES	YES
Armação de Búzios	RJ	0,24821	18204	1394	YES	YES
Sapezal	MT	0,25207	7866	1288	NO	NO

5. Concluding remarks

In this paper we have estimated the DEA technical efficiency for 4796 Brazilian municipalities by applying a “jackstrap” method, which combines Bootstrap and Jackknife resampling techniques to eliminate the effect of outliers and measurement errors in the data set. For that purpose we used a two-step procedure: first, we calculated leverage value for each municipality in order to identify potential outliers; second, we computed CCR and BCC efficiency scores by excluding (using different probability schemes) those communes which presented the highest leverage. The computed efficiency scores, as well as their rank, proved to be very robust for both variants, thus increasing the credibility of the estimated frontiers.

Corroborating previous results, efficiency results for the Brazilian municipalities show a clear relationship between the size of the municipality and its efficiency scores. Indeed, under both DEA variants, smaller cities tend to be less efficient than larger ones hence indicating that the quality of the frontier adjustment improves significantly as the size of the municipality increases. We present some arguments that may explain to some extent these findings, such as economies of scale, the excess spending due to substantial royalties, and underestimate of population due to tourism. However, such effects require further, more careful examination.

It should also be noted that inefficiency of some municipalities may be due to exogenous factors that cannot be controlled, such as natural and climatic factors, political issues, demographic and socio-economic characteristics, that have not been taken into account in our analysis. Therefore, the natural extension of our current investigation would be to separate the effects of the exogenous factors from those related to the technical aspects of the productive process, in order to obtain a “pure” measure of technical efficiency for the Brazilian municipalities.

Finally, because of the sheer size of the data set, it is impossible to include here a table with our final efficiency results for all the municipalities. The results may be obtained from the authors upon request, in electronic form.

7. References

- [1] Farrell, M. (1957) “The Measurement of Productive Efficiency.” *Journal of the Royal Statistical Society Series A* 120: 253-281.
- [2] Charles, A., Cooper, W.W. and Rhodes, E. (1978) “Measuring Efficiency of Decision Making Units”, *European Journal of Operational Research* 1: 429-44.
- [3] Banker, R. D., Charnes, A and Cooper, W.W. (1984) “Some Models for Estimating Technical and Scale Efficiencies in Data Envelopment Analysis,” *Management Science* 30: 1078-1092.
- [4] Färe, R., Grosskopf, S. and Lovell, C. K. (1985) *The Measurement of Efficiency of Production*. Boston: Kluwer-Nijhoff Publishing.

- [5] Tulkens, H. (1993) "On FDH Efficiency Analysis: Some Methodological Issues and Applications to Retail Banks, Courts, and Urban Transit," *Journal of Productivity Analysis* 4: 183-210.
- [6] Vanden Eeckaut, Tulkens, H. and Jamar, M. A. (1991) "A Study of Cost-Efficiency and Returns of Scale for 235 Municipalities in Belgium." Core Discussion Paper_n° 9158, CORE, Université Catholique de Louvain.
- [7] Deprins, D., Simar, L. and Tulkens, H. (1984) Measuring Labor Efficiency in Post Offices.
- [8] Sampaio de Sousa and Souza Ramos, F. (1999) "Measuring Public Spending Efficiency in Brazilian Municipalities: A Non Parametric Approach" in Westermann, G., Ed., *Data Envelopment Analysis in the Service Sector*. Wiesbaden: DUV, Gabler.
- [9] Sampaio de Sousa and Souza Ramos, F. (1999a) "Eficiência Técnica e Retornos de Escala na Produção de Serviços Públicos Municipais." *Revista Brasileira de Economia* 53: 433-461, 1999
- [10] Stosic, B. and Sampaio de Sousa, M.C. (2003) "Jackstrapping DEA Scores for Robust Efficiency Measurement." Mimeo.
- [11] Wilson, P. (1993) "Detecting Influential Observations in Data Envelopment Analysis." *Journal of Productivity Analysis* 6: 27-45.
- [12] Wilson, P. (1995) "Detecting Influential Observations in Deterministic Non-Parametric frontiers models." *Journal of Business and Economic Statistics* 11: 319-323.
- [13] Banker, R. D and J.L. Gifford (1988) "A Relative Efficiency Method for the Evaluation of Public Health Nurse Productivity." Mimeo.
- [14] Seaver, B. L. and K. P. Triantis (1989). "The Implications of Using Messy Data to Estimate Production-frontier-based Technical Efficiency Measures." *Journal of Business and Economic Statistics* 7: 49-59.

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