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Can Education Targets be Met Without Increasing Public Spending? An Analysis for Brazilian Municipalities

Fabiana Rocha
University of São Paulo

Plinio Portela de Oliveira
Brazilian National Treasury Secretariat

Janete Duarte
Brazilian National Treasury Secretariat

Sérgio Ricardo de Brito Gadelha
Brazilian National Treasury Secretariat

Luis Felipe Vital Nunes Pereira
Brazilian National Treasury Secretariat

Abstract

The purpose of this paper is to assess the efficiency of public spending education by local governments in Brazil and to evaluate whether the financial resources that municipalities allocate to education are sufficient to guarantee that they achieve the quality targets established for 2021. We assume that family background (measured by parent´s education) is a fixed input in the short run, and that municipalities only have control over the amount they spend on education. Results indicate that the amount of non-efficiently spent resources is significant and that most local governments could actually meet their targets without additional resources, only by moving to best practices.

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Contact: Fabiana Rocha - frocha@usp.br, Plinio Portela de Oliveira - plinio.oliveira@fazenda.gov.br, Janete Duarte - janete.duarte@fazenda.gov.br, Sérgio Ricardo de Brito Gadelha - sergio.gadelha@fazenda.gov.br, Luis Felipe Vital Nunes Pereira - luis.n.pereira@fazenda.org.br.

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1. Introduction

Education has been one of the primary concerns of Brazilian public policy since the redemocratization process culminated in a new Constitution, which was enacted in 1988. Since then, municipalities have taken responsibility for the provision of most pre-primary, primary and lower secondary public education. Since a fund for financing subnational spending on education (FUNDEF) was created in 1998, all municipalities have been provided with a minimum level of financial resources *per student*. This is believed to have strongly encouraged municipalities to proceed with the decentralization established by the Constitution; it is also believed to have prompted municipalities to stimulate school attendance. In fact, school attendance rates among the school-aged population have been steadily approaching universalization.

The effectiveness of student learning has also been a major concern. At the beginning of the 1990s, the Ministry of Education began developing a system for assessing learning achievements; this system is now well established and is internationally regarded as well conceived [Bruns et al (2012)]. In its current formulation, the biannual assessment makes it possible to compare the performance of all public schools with each other and to do so on an intertemporal basis. Performance is measured by IDEB (Basic Education Development Index), which assesses students' literacy in the fifth and ninth grades and also pass rates. The index is fully disclosed on a *per school* and *per municipality* basis. In addition to the positive effect of performance visibility, targets at the school level were established and are supposed to be met by 2021, with the aim of approaching the 2003 average OECD level[1].

Increasing resources have been assigned to the provision of public education in Brazil. According to INEP, a federal institute linked to the Ministry of Education, public expenditures on primary and lower-secondary education *per pupil* in 2011 nearly tripled, in real terms, the expenditures of 2000. Yet, this figure is substantially lower than those observed among the countries with the best PISA results[2], which might be considered reasonable evidence that further resources will be necessary if Brazil is to achieve a comparable level of excellence. However, public finance figures show signs that, in the short run, there might not be sufficient fiscal spaceto spend much more on Education.

There is ample international evidence that the relationship between higher resource allocations to education and school performance is weak or that, in some cases, it does not exist at all [Hanushek and Kimko (2000); Hanushek and Luque (2003)]. For Brazil, Amaral and Menezes-Filho (2008) also conclude that the effect of spending on school performance, measured by the results of the nationwide standardized test known as *Prova Brasil*, is negligible and, in most of the adopted specifications, statistically insignificant. However, these results are based on the specification and estimation of linear models for the relationship between the quality of education and its determinants.

The present paper moves away from this literature in that it is not concerned with average effects but rather with better practices. It aims at assessing the efficiency of public provision of primary and lower secondary education at the municipal level, considering only the main providers (local governments). The greater the assessed inefficiency, the greater the room to improve performance without additional resources. In light of the estimated frontiers, we are able to identify which municipalities can achieve the 2021 targets without additional resources.

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[1] Targets were defined after a comparative basis was established between PISA and IDEB rates.

[2] Considering countries with available data (UNESCO). INEP's numbers were used for Brazil's enrolments and expenditures as percentage of GDP.

Since the seminal application of Data Development Analysis (DEA) to education by Charnes et al. (1981), several papers have attempted to assess the efficiency of education services from both in-country and cross-country perspectives [Ruggiero and Vitaliano (1999), Clements (2002), Gupta et al. (2002), Afonso and St. Aubyn (2005, 2006), Herrera and Pang (2005), Gimenez et al. (2007), Sutherland et al. (2009), Portela and Camanho (2012)]. A few papers have also sought to assess the efficiency of education provision at the school and municipal levels in Brazil using DEA models and variants [Almeida and Gasparini (2011), Gonçalves and França (2013)].

The paper contributes to the literature in two ways. First, we take into account that environmental conditions (different economic and social conditions, different geographies, different sectoral production characteristics, etc.) may have strong effects on municipalities' performance. Therefore, we are interested in estimating the relative performance of municipalities within a certain group and also in comparing their performance across groups. To do this, the efficiency of municipalities will be measured relative to a common metafrontier, i.e., the boundary of an unrestricted technology set. Efficiency will also be gauged in terms of group frontiers, defined as frontiers of restricted technology sets, where restraints stem from the different characteristics of the production environment of municipalities. More precisely, efficiency relative to the metafrontier will be broken down into a component that measures the distance of an input-output point from the group frontier and a component that measures the distance between the group frontier and the metafrontier. The former component constitutes the usual measures of technical efficiency, whereas the latter one takes into account the restrictive nature of the production environment (O'Donnell et al. (2008)). Second, we make a distinction between the inputs that is not usually made in the literature: we assume that parents' schooling is a fixed short-run input and that it lies outside a municipality's immediate discretionary power; thus, we seek to assess only improvements in the discretionary (controllable) domain, that is, in spending itself. In other words, we assume that it is possible to reduce spending proportionally without using more of the fixed input (parents' schooling) and without producing a smaller amount of output.

The paper is organized as follows. Section 2 describes the methodology used to calculate the efficiency of municipalities. Section 3 introduces the variables used as outputs and inputs and discusses the results of the estimates. Section 4 summarizes the major conclusions.

2. Methodology

Usually, when production possibility frontiers are estimated to evaluate public spending efficiency, the heterogeneity of the countries, states, and municipalities that form the sample is not taken into account. Estimating a global production frontier for municipalities, for example, thus implies assuming that municipalities share common production technology. This assumption, however, does not seem to be consistent with reality, as the different environments in which municipalities operate influence mayor and manager capacities and desires to implement technological innovation. Not only do municipalities make choices based on different input and output combinations, but they also have distinct technology sets owing to differences in their physical, human, and financial capital stocks, economic infrastructure, fund availability, etc.

Estimating only separate frontiers for municipality groups (subsamples) instead of using a common frontier for the whole sample does not solve the problem, given that the resulting technical efficiency scores for municipalities belonging to different groups are not directly comparable.

An alternative is to use the metafrontier approach. The metafrontier function is an envelope curve of production points of the most efficient municipalities. Each municipality can operate on a different production possibility frontier segment according to its available funds, technology adoption and diffusion, and economic environment.

Battese and Rao (2002) compared firm technical efficiencies in different groups that might not have the same technology using a stochastic metafrontier production function. They assumed that there are two different data-generating process types, as follows: one related to the stochastic frontier, which is estimated using group-specific data, and another related to the metafrontier, which is estimated using data from the whole sample. The resulting technological gap provides information on the ability of firms in a given group to compete with firms from different groups within the same industry. It shows the technology gap size for a given firm whose current available technology is inferior to the available technology of all firms represented by the metafrontier. The drawback of this approach is that metafrontier production function values can be lower than deterministic components of group stochastic frontier production functions.

Battese et al. (2004) solved this problem by explaining deviations between observed outputs and group frontiers using single data-generating process specification. In addition, they defined metafrontier as a function that envelopes deterministic components of the estimated stochastic frontier for several groups. However, they estimated the metafrontier only using the stochastic frontier production model with time-varying inefficient effects.

Finally, O'Donnell et al. (2008) used both non-parametric (Data Envelopment Analysis - DEA) and parametric (several stochastic frontier approaches) to estimate metafrontiers and group frontiers, besides breaking down performance differences across firms into technical efficiency and technology gap effects.

To estimate metafrontier and group frontiers, we use DEA. There are two available DEA model types. One is the output-oriented model, in which inputs are held constant and the aim is to maximize proportional output increases, and the other one is the input-oriented model, in which output is held constant and the aim is to seek maximum proportional input reduction[3].

As the goal of this study is to determine whether municipalities could use fewer funds to achieve their current education results, an input-oriented model will be used. In other words, a metafrontier cost function will be estimated, which is the specific cost frontier envelope for municipality groups.

The metafrontier estimation will follow the method proposed by O'Donnell et al. (2008), whose estimation procedure consists of the following steps:

1) Classifying all municipalities into $S_1, S_2, \dots, S_k$ sets.
2) Estimating α_i^S efficiencies for each i municipality within its correspondent set.
3) Applying DEA to the whole sample to obtain the efficiency of each municipality in relation to α_i^M metafrontier.
4) Calculating α_i^M / α_i^S, which are called technological gap ratios by Battese et al. (2004) and metatechnology ratios by O'Donnell et al. (2008) and are denoted by MTR_i.

The metatechnology ratio basically assesses the technology gap size for a given municipality set whose current adopted technology lags behind the technology available for all municipalities, represented by the metafrontier cost function. At a given output level, the

[3] The two types of models give the same efficiency scores under constant returns to scale technology, but they give different scores under variable returns to scale (VRS) technology.

metatechnology ratio is defined as the smallest possible cost within the metafrontier divided by the smallest cost in the specific set. Thus, the higher the metatechnology ratio mean value for a given set, the better is the production technology it has adopted (O'Donnell et al., 2008).

In practice, technical efficiency related to the metafrontier cost is obtained using the following decomposition:

$$\alpha_i^M = \alpha_i^S \times MTR_i \qquad (1)$$

Where the first element is the conventional technical efficiency measuring the deviation of the municipality's effective cost from the specific group cost frontier, while the second element measures the deviation of the specific group frontier from the metafrontier cost function. The metafrontier cost efficiency score indicates how good the performance of a municipality is in relation to the expected performance of pairs with the best practices and exploring the best technology available for all groups to produce a certain product amount.

To perform step 2, DEA was applied to inputs and outputs of municipalities from each group to build a group-k frontier. In fact, to estimate the waste of resources in the field of education for each municipality, we use directional distance functions. In traditional efficiency measures, all inputs are reduced by the same factor, that is, all inputs are regarded as discretionary. In the directional distance functions approach, it is possible to specify which inputs are discretionary and also the extent to which inputs can be reduced.

Our model is based on a production process with n outputs and m inputs, where $y \in \mathbb{R}_+^n$ is the vector of quantities of output and $x \in \mathbb{R}_+^m$ is the vector of quantities of inputs. An activity is expressed by $(x, y) \in P \subset \mathbb{R}_+^m \times \mathbb{R}_+^n$ and contains the input-output combination of a given decision making unity (DMU) which, in our case, is a municipality. The set formed by all feasible activities is called the production possibility set (T).

We define $d \in \mathbb{R}_+^m$ as a vector that determines an arbitrary direction from which inputs can be reduced. For instance, in the case where $m = 3$, vector $d = (1,0,0)$ defines the direction of x_1 to reduce the inputs, which leads to the understanding that only input x_1 is discretionary.

Given an activity (x^0, y^0), we define the directional distance function or excess function as:

$$e = e(x^0, y^0, T, d) = \max\{e \in \mathbb{R}_+ \mid (x^0 - ed, y) \in T\}$$

Excess $e(x^0, y^0, T, d)$ corresponds to the number of units in the input basket, defined by vector d, used in excess of the efficient spending to produce y^0, such that the resulting activity belongs to the production possibility set. Hence, e can be interpreted as wasted inputs. It should be noted that this approach differs from the traditional radial construction, as it reduces only the discretionary inputs.

The additive variant of the DEA model (see Ray [15] pp.120, Bogetoft and Otto [16] pp. 121) can be used to calculate e and consists of the following linear problem:

$$Max_{e,\lambda_1,\ldots,\lambda_k}\, e$$

$$s.t.\quad x^0 - ed \geq \sum_{k=1}^{K} \lambda_k X^k$$

$$y^0 \leq \sum_{k=1}^{K} \lambda_k Y^k$$
$$\lambda \in \Lambda^k(\gamma)$$

Where $\lambda \in \Lambda^k(\gamma)$ is a constraint imposed on weights λ, which defines the returns to scale.
IDEB 2011 is taken as output, and current expenditures *per student* (summarizing all costly inputs) and average parents' schooling (a *proxy* for family background) are considered as inputs. The assessment of municipalities' efficiency is performed using DEA methodology, with variable returns to scale (VRS)[4] and considering parents' schooling as rigid, so that only the expenditures are contracted toward the estimated frontier, instead of the standard radial contractions. For the sake of comparability, a standard DEA model is also applied, although the interest actually lies in the non-radial one.
Therefore, we have:
X^k: a $K \times 2$ input matrix, in our case: $X = (\text{Expenditures per student, Parent´s education}_j)$ j=1,...K
Y^k: a $K \times 1$ output matrix, in our case: $Y = (IDEB_j)$ j=1,...K
d: Direction vector. In this case, as X=(Expenditures per student, Parent´s education), to calculate wasted resources relative only to spending (discretionary input in the short run), we use vector $d = (1,0)$;

The result of e gives the directional waste of spending.

To perform step 3, that is, to identify the metafrontier, DEA methodology was applied to the inputs and outputs of all municipalities.

Once we estimate municipalities' technical efficiencies with respect to the metafrontier and group frontier, we can perform step 4 straightforwardly and estimate the metatechnology ratio.

Metafrontier analysis is an approach based on DEA models that enables comparison between different groups while taking into account any heterogeneity between them. A metafrontier may be considered as an umbrella (upper or lower) of all possible frontiers, and it aims to provide a homogeneous boundary for all heterogeneous decision-making units. This model, therefore, produces the maximum output from a given input using the best technology.

3. Results

IDEB 2011 is taken as the measure of output, and current expenditures *per student* (summarizing all costly inputs) and average parents' education (a *proxy* for family background) are considered as inputs.

The assessment of municipalities' efficiency is carried out using DEA methodology, with variable returns to scale and consideration of parents' schooling as rigid, so that only the expenditures are contracted toward the estimated frontier. Input orientation is chosen to estimate the fractions of allocated resources that are not yielding the maximum possible return.

From the universe of 5,564 municipalities, 606 were excluded due to missing values. Another 30 were regarded as outliers according to the method formulated by Andrews and

[4] Constant returns to scale are not suitable for DEA models with ratio data, as is the case for *per student* expenditure [Hoolinsworth and Smith (2003)].

Pregibon (1978), later generalized to the multi-output case by Wilson (1993) and implemented in the FEAR package, which can be used in the R software environment [Wilson (2008)].

The remaining 4,928 municipalities are split into four categories according to their population magnitude, so that the Meta-frontier framework conceived by O'Donnel et al (2008) can be applied. Intra-group frontiers are estimated, and these technologies are compared to the meta-technology, revealing important differences in production environments among groups. Finally, virtual DMUs (where the current output levels are substituted by the respective 2021 targets) are assessed in light of the same technology, revealing which municipalities would be able to achieve their respective targets without additional financial resources. Calculations were carried out using the Benchmarking package, also linked to the R environment [Bogetoft and Otto (2011)].

We choose to group the municipalities according their population for three reasons.

First, articles 48, 48-A and 73-B of Brazilian Fiscal Responsibility Law use the population size to check the fiscal transparency of local governments. We have therefore an exogenous classification of municipalities by size that can be readily used. In order to verify if municipalities are attending their fiscal targets, the Fiscal Responsibility Law split them into three groups: up to 50,000 inhabitants, between 50,000 and 100,000 inhabitants, and over 100,000 inhabitants. Since the third group includes very heterogeneous municipalities, we split into two subgroups: municipalities with up to 500,000 inhabitants and municipalities with over 500,000 inhabitants.

Second, since we use only one variable to define the groups, we avoid the problem of choosing a methodology to form the clusters when more than one variable is used to define similarity.

Third, scale is an important determinant of municipality (in)efficiency. Small population leads to an increase in the average costs of public health care delivery, which hinders the exploitation of scale economies associated with the production of these services and, ultimately, associated with suboptimal use of funds.

Table I shows that our sample represents 90% of all local governments in Brazil, and corresponds to an annual average of 15.7 million students over the period analyzed. The set of the smallest municipalities represents nearly half the enrolments (48%).

Table I: Municipality groups and respective enrolments

Group	Population	Municipalities	Municipalities (*)	Average number of students (**)
1	0 – 50 thousand	4,956	4,344	7,499,291
2	50 – 100 thousand	325	319	2,396,621
3	100 – 500 thousand	245	234	3,645,864
4	More than 500 thousand	38	31	2,141,632
Total		5,564	4,928	15,683,408

(*) Missings and outliers excluded.
(**) Average annual enrolments for the 2008-2011 period taken for each municipality.

The average technical efficiencies and meta-technology ratios are displayed in Table II. The first four rows show the average efficiencies for municipalities within each group in light of the respective intra-group technology. The fifth row gives the total averages, still considering each municipality's intra-group frontier. The last row shows the average estimated efficiency considering the meta-technology, determined by all municipalities, whose frontier envelops the intra-group counterparts. The averages are taken by assigning to each municipality its number of enrolments as weight.

One can note that efficiencies estimated by the non-radial VRS model are smaller than those stemming from the radial VRS one, which means that considering parents' schooling as rigid reveals that current expenditures could be reduced further. Considering the intra-group technologies, efficiency increases with the size of municipalities, and smaller municipalities are estimated to be able, by adopting best practices, to reduce their current expenditures *per student* by nearly 45% on average, without consequences to the output levels. Furthermore, larger municipalities still seem to have significant room to improve their performance.

Table II: Average technical efficiencies and meta-technology ratios

Groups	Municipalities	Students	Radial VRS efficiency	Non-radial VRS efficiency	Radial VRS MTR
1	4,344	7,499,291	0.626	0.554	0.933
2	319	2,396,621	0.654	0.622	0.886
3	234	3,645,864	0.723	0.629	0.668
4	31	2,141,632	0.856	0.660	0.413
Total	4,928	15,683,408	0.682	0.594	0.793
Meta-technology	4,928	15,683,408	0.530	0.464	-

On the other hand, the meta-technology ratios (MTRs) are significantly higher in the two groups of smaller municipalities. In fact, these municipalities determine the meta-frontier because only the corresponding intra-group frontiers eventually touch the former (points with MTRs equal to one). This is evidence that the provision of education has been taking place under more adverse production environments in the larger municipalities compared to the smaller ones. The municipal delivery of primary and lower secondary education has annually represented a typical amount of USD 32 billion during the 2008-2011 period in the Brazilian municipalities considered here (Table III). A major (43%) portion has been spent by small local governments, which serve nearly half of the students. These figures show how important it is to assess the provision of education taking place in those areas. Not only are the expenditure and enrolment figures huge in these municipalities, but, according to estimates of intra-group frontiers, they account for the largest fraction of inefficiently spent resources, in absolute and relative terms. In fact, nearly half the resources could have been spent somewhere else, while still leaving outputs unchanged, and the US$ 6.7 billion represents nearly half the total figure. The other municipalities are also estimated to have been inefficiently spending significant resources. The overall waste reaches 44%.

Table III: Non-efficiently spent resources according to intra-group technologies

Groups	Municipalities	Actual spending	Radial VRS (2011 USD billions)	Non-radial VRS (2011 USD billions)	Radial VRS (%)	Non-radial VRS (%)
1	4,344	13.7	5.7	**6.7**	41.5	**48.9**
2	319	4.2	1.6	1.7	37.3	41.0
3	234	7.6	2.3	3.2	30.5	41.5
4	31	6.4	1.0	2.5	16.0	39.2
Total	4,928	32.0	10.6	**14.1**	33.2	44.1

Considering each municipality as a virtual DMU where the respective targets take the place of current output levels, one can assess which municipalities could possibly meet their respective objectives without additional resources in light of the estimated intra-group technology. As Table IV shows, only a few of the considered local governments have already managed to achieve their targets. Nevertheless, the majority of the remaining municipalities could also have accomplished the same. The evidence – due to the adopted methodology and assumptions as well as the data used – indicates that below 10% of the assessed local governments actually need further resources to achieve their respective targets. Furthermore, those able to achieve their targets could do so and even spare slightly more than one third of their spent resources, which means that either the targets could be more audacious or the spent resources could be reduced.

Table IV: Municipalities that could meet their respective targets without further resources

Groups	Munici-palities	Already met the target	Could meet the target	Could meet the target (%)	Actual spending	Inefficient expenditures(*) (2011 USD)	Inefficient expenditures(*) (%)
1	4,344	242	3,985	97.3	13.3	4.9	37.3
2	319	1	166	52.4	2.3	0.5	23.8
3	234	2	110	47.9	4.2	1.3	32.1
4	31	-	3	9.7	0.5	0.2	34.7
Total	4,928	245	4,264	91.5	20.2	7.0	34.6

(*) Under the hypothesis that the able-to-meet-targets municipalities succeeded in reproducing best practices and expanding outputs to respective intra-group frontiers.

4. Conclusions

Using a VRS DEA methodology with one of the inputs regarded as non-discretionary, and using a meta-frontier approach, this paper provides evidence that a substantial amount of resources are spent inefficiently on primary and lower-secondary municipal education in Brazil. This has particularly relevant consequences considering both the scarcity of fiscal space to substantially increase expenditures and Brazil's slight accomplishments in terms of students' literacy.

Regarding efficiency as rigid in the short run, and because Brazilian municipalities spend much less *per student* than the countries with the best PISA performances, one could not wisely advise a reduction in the financial resources allocated to primary and lower-secondary education. Nevertheless, efforts should be made to improve performances, focusing mainly on small municipalities, which seem to have the most room for improvement and account for a major fraction of enrolments. Performance improvement is expected to have positive repercussions on economic growth, which would actually make more resources available, triggering a virtuous circle.

The obtained estimates indicate that most Brazilian local governments could meet their respective targets without additional resources.[5] In fact, most of them could actually go further. Because those targets are established on a comparative basis with PISA accomplishments by OECD countries, the dissemination of best practices throughout Brazilian municipalities would actually bring Brazil much closer to international standards.

This paper also provides strong evidence of the adverse production environment underlying municipal education provision in most populous municipalities. Further research should investigate which characteristics are associated with that adversity and how to mitigate it to increase the production possibilities of those municipalities. Likewise, there is an extensive literature investigating optimal reforms in education provision, which might reveal practices still not adopted in Brazil that could expand opportunities to improve performance [Bruns et al (2011), Bruns et al (2012), Bruns (2013), Veloso (2011)].

Further research should also investigate which factors underlie the estimated inefficiency. This would be carried out on a second stage, through a Tobit regression or by adopting the methodology conceived by Simar and Wilson (2007).

The present research is part of a broader project that aims to measure efficiency in the provision of education and health by local governments in Brazil. Regarding education the plan is also to implement a school-level analysis to deepen the picture given by the municipality-level analysis. Sutherland et al. (2009) use similar approach and estimate the efficiency in the primary and secondary education of OECD countries using both school-level and country-level data. The efficiency literature applied to the public sector foucs on the comparison of municipalities, counties, states or countries, but the school-level analysis is important because certainly there is school variability within municipality that must be taken into account. Besides it allows us to use, instead of spending, physical inputs like teachers per student and computers per student, and to broden the set of inputs including the experience of teachers and their level of education to deal with que qualitative aspects of the educational process. The efficiency analysis at the municipality-level unfortunately does not treat the educational process in all is complexity and ends up reducing it to a simple result of socio economic conditions and economic resources. It is not unnecessary to observe that, the interest of this paper goes beyond Brazil. Budgetary constraints must be respected in all economies, and efficiency is a tool to relax them. Therefore, a better use of available resources should be a concern of all governments at all times, especially during economic downturns.

5. References

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[5] As correclty observed by one of the referees, in fact the results are not able to highlight the weaknesses of the education system. They show that most of the municipalities do not need for additional resources to improve their results but say nothing about how they can achieve the quality targets with available resources.

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