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IMPLICATIONS OF BRAZILIAN INSTITUTIONAL GUIDELINES ON EDUCATIONAL EFFICIENCY

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DISCUSSION PAPER

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CONTENTS

ABSTRACT

This paper aims to investigate the relation between inefficiency in the Brazilian education system and municipal wealth, discussing how the actual legislation possibly influences it. To that end, we apply a stochastic frontier model which accommodates covariates in the asymmetric error component to analyze the impact of the GDP per capita on the inefficiencies. This methodology is applied to a panel dataset from the Metropolitan area of Porto Alegre municipalities over the period 2007-2017. The results indicate a positive effect, suggesting that richer municipalities are less efficient in allocating their resources.

Keywords: educational inefficiency; Fundeb; stochastic frontier analysis; Bayesian inference.

SINOPSE

Este trabalho tem como objetivo investigar a relação entre a ineficiência no sistema educacional brasileiro e a riqueza municipal, discutindo como a legislação atual possivelmente exerce influência na ineficiência. Para isso, aplicamos um modelo de fronteira estocástica que acomoda covariáveis na componente de erro assimétrico para analisar o impacto do PIB *per capita* sobre as ineficiências. Esta metodologia é aplicada a um painel de dados da área metropolitana dos municípios de Porto Alegre durante o período 2007-2017. Os resultados indicam que os municípios mais ricos são menos eficientes na alocação dos seus recursos.

Palavras-chave: ineficiência educacional; Fundeb; fronteira estocástica; inferência bayesiana.

1 INTRODUCTION

The basic education is, albeit partially, provided by different governments around the world. This investment is funded by taxpayers and, consequently, it is associated to the productive capacity to generate wealth, it means, the Gross Domestic Product (GDP) per capita. Considering its relevance and due to the limited resources available in the public administration that also supplies services like healthcare, law enforcement, security and others, it is important to ensure an efficient allocation of this capital. In the education economics literature, there is empirical evidence which supports that an increase in financial funding assigned to education does not necessarily imply a better performance in standardised assessments of educational attainment (Hanushek and Luque, 2003; Glewwe et al., 2011; Monteiro, 2015). However, the Education at a Glance 2017 (OECD, 2017) presents an association between developed countries from the Organisation for Economic Co-operation and Development (OECD) and better results in the PISA (Programme for International Student Assessment) test.

As a result, it is possible to infer that school achievements are not only related to the total amount available, but also to an efficient allocation of it. Afonso and Aubyn (2006) explore these ideas and propose a two-stage approach in which the efficiencies are obtained in the first step and, in the second, they estimate the relationship between the previous results and the GDP per capita. From PISA data of twenty five OECD countries, the authors conclude that the efficiency is strongly related to GDP, in other words, the richer a country is, more efficient it is in providing a better education. Nonetheless, is this relationship also observed for municipalities within a country? Oliveira and Santos (2005) evaluated the Portuguese schools efficiencies and analyzed the influence of the GDP per capita of municipalities where they were located, obtaining a not significant result. In the Brazilian case, this question is particularly interesting because the municipalities 2 face severe fiscal restrictions and major challenges in the area. In addition, the Law of National Education Guidelines and Bases contains a peculiar topic, the Law No. 9,394 of 1996. This legislation states that municipalities must allocate at least 25% of their budget revenue to public education.

Therefore, the main hypothesis of this paper is: wealthy municipalities are less efficient in the allocation of their resources due to the obligation of investing an amount that is possibly higher than the necessary. To confirm our hypothesis we intend to investigate the relation between the GDP per capita of municipalities and their inefficiencies. To that end, an extension that accommodates covariates in the asymmetric error component of the spatial stochastic frontier model introduced by Schmidt et al. (2009) is proposed. The methodology is applied to a panel dataset from the 34 municipalities which integrates the Metropolitan area of Porto Alegre over the period 2007-2017.

The remainder of the paper is organized as follows. Section 2 brings a brief literature review of the main methods to measure efficiency in education economics and underlines some interesting outcomes and outlines the Brazilian legislation and its connection with the concept of adequacy in school finance. Section 3 introduces the methodology and details of the inference process. In section 4, the dataset and the results are presented and discussed. At last, section 5 brings the main conclusions.

2 BACKGROUND

2.1 Literature review

"What matters more are the choices countries make in how to allocate that spending and the policies they design to improve the efficiency and relevance of the education they provide" (OECD, 2013). In this sense, Angel Gurria, OECD Secretary-General, underlines the importance of an efficient public spending and a rational allocation of these resources. Since education is relevant for promoting several outcomes, such as cognitive and non-cognitive skills and economic growth (Cunha, Heckman and Schennach, 2010; Hanushek and Kimko, 2000), this is a topic of intense debate among policy makers, teachers and other stakeholders. The analysis of education provision efficiency consists in defining a technology function to produce knowledge, which represents the maximum output that can be achieved given a provision. Then, a system is considered efficient if its producers make an effective use of available inputs. In an inefficient system, there is a possibility of increasing attainments for a given spending level, or decreasing expenditure for given attainments (De Witte and López-Torres, 2017).

However, defining and estimating a production function is not a trivial task, once it is necessary to specify the relevant inputs. Glewwe et al. (2011) reviewed the literature about school resources and educational outcomes in developing countries and concluded that most schools and teachers characteristics are not statistically significant to explain the learning process. In addition, the results are influenced by several factors that are beyond the control of the evaluated observation. Coleman et al. (1966) observed that investments explain only 10% of academic achievements, while the remainder percentage depends on other economic variables and students family environment, which are known as non-discretionary variables.

Therefore, different specifications and methods have been applied to study the importance of structural, institutional and socioeconomic variables on educational achievements and efficiency scores. Nonetheless, it is possible to identify two main modeling techniques that are implemented in the literature, the first is known as the Data Envelopment Analysis – DEA (Charnes, Cooper and Rhodes, 1978) and the second as Stochastic Frontier Analysis – SFA (Aigner, Lovell and Schmidt, 1977; Meeusen and van Den Broeck, 1977). Commonly, both techniques are employed as a first step in an empirical strategy based on a two-stage procedure in which the second stage lies on a regression-type model between the efficiency scores and explanatory variables.

Bradley, Johnes and Millington (2001) and Worthington (2001) provide a list of studies conducted in several countries that illustrates different applications of DEA methodology. Agasisti (2013), for example, measures the performance of Italian secondary school, investigates which factors affect efficiency through a Tobit regression and concludes that there is a potential role for better results by increasing competition. Considering the SFA methodology, a broad literature was also developed (Izadi et al., 2002; Lenton, 2008; Kuo and Ho, 2008). For instance, Lewis, Pattinasarany and Sahn (2011) analyzed the public elementary schools in Indonesia and the results suggest that the outcomes might be enhanced even with a reduction in total spending.

Furthermore, there are some alternative methods. Deutsch, Dumas and Silber (2013) applied the corrected least squares method (Richmond, 1974) to estimate the efficiency of five Latin American countries and obtained that individual efficiency is likely to be inuenced by increments in public debt caused by expansions in education access. Thieme, Giménez and Prior (2012), on its turn, used directional distance functions (DDF) to evaluate Chilean urban schools and identified that the most important source of inefficiency is the resource endowment effect. The authors also argued that when specific variables concerning the amount allocated are disregarded, the performance is undervalued.

Regarding the Brazilian case, Carvalho and Sousa (2014) and Gonçalves and França (2013) applied DEA methodology to dataset from Brazilian municipalities and northeastern and southeastern public schools respectively. The first paper indicated that, even discounting the environmental factors, improvements can be made. The second established a positive relation between efficiency gains and decentralized management. Adopting an approach based on quantile estimators, Oliveira, Souza and Annegues (2018) suggest that management autonomy is not a determining factor for efficiency degrees in Brazilian public schools. Another problem related to the allocation of resources for education in Brazil is the corruption. Ferraz, Finan and Moreira (2012) examined if missing resources due to corruption affect student outcomes using variation in this incidence across municipalities. The findings suggest a significant negative association between corruption and the school performance of primary school students.

It is important to mention that literature is not convergent, and conclusions vary according to method, period and country analyzed. Kirjavainen (2012) fitted different stochastic frontier models for panel data to estimate a production function and the efficiency of Finnish general upper secondary schools. The estimates pointed that inefficiency and rankings based on their scores diverge considerably depending on the type of the applied model.

2.2 Adequacy in school finance and Brazilian legislation

Adequacy in school finance is a term implemented in education economics to define the amount of funding required to produce a desired level of student performance. According to Odden (2003), determining sufficient revenue levels involves the following steps: identifying the costs of effective programs and strategies, converting these investments into appropriate school finance structures, certifying that the resources are used in schools to produce the aspired results. Ruggiero (2007) highlights that these levels vary in accordance with the socioeconomic characteristics of municipalities. For example, locations in which pupils encounter precarious conditions should invest more.

The concept introduced above is applied on the design of public policies in order to guarantee a minimum expenditure in education (Hanushek, 1994). In Brazil, the Law No. 11,494 of 2007 established the Fund for Basic Education and for Enhancing the Value of the Teaching Profession (Fundeb) with the aim of ensuring a minimum investment per pupil. This mechanism consists of a state account in which the municipalities deposit 20% of the revenue collected from taxes. This amount is redistributed following students profile and the number of registrations in the public network.

Furthermore, the Law No. 9,394 of 1996 establishes that states and municipalities must assign at least 25% of their budget revenue to the maintenance and development of the educational public system. In addition, the objective 20 in the National Education Plan (PNE), Law No. 13,005/2014, aims the expansion of spending in education to 10% of the national GDP until 2024. To that end, it was proposed an index that specifies a minimum amount per pupil to accomplish the desired standard. This index is based on relevant inputs for the teaching-learning process like infrastructure, instructional materials, teacher qualification, remuneration, just to mention a few.

Towards this scenario and the extensive literature about inefficient allocation of resources in education summarized in section 2.1, Monteiro (2015) evaluated the impact of higher spendings observed on the oil producing municipalities that were benefited by higher revenues from royalties over the period of 2000 through 2010. The author concluded that an increase of 15% on revenues and, in consequence, on education funding was not converted into better results in comparison with other municipalities from the Brazilian coast. Therefore, it is plausible to think that locations where larger GDP per person are observed have less incentive for an efficient management given the current legislation.

3 METHODOLOGY

Suppose that observations are available in the form of balanced panel data for N municipalities across T times. Let y_{it} be the logarithm of the output of the municipality i on time t, the stochastic frontier model is defined by the following equation

$$y_{it} = g(r_{it}, \theta) - u_{it} + \varepsilon_{it} \quad (1)$$

where $(r_{t'}, \theta)$ is the production function, r_{it} is a vector of inputs, and θ is a vector of parameters that describe the effect of each input on the output y_{it}. The component u_{it} follows an asymmetric positive distribution and models the inefficiency of unit i on time t. The random error, ε_{it}, is assumed independent of u_{it} and follows a Gaussian distribution centred at zero with variance σ^2, that is, $\varepsilon_{it} \sim N(0, \sigma^2)$.

Considering the distribution of the inefficiency component, there are different proposals in the literature: the exponential (Meeusen and van Den Broeck, 1977), the half normal (Aigner, Lovell and Schmidt, 1977), the truncated normal (Stevenson, 1980), the gamma (Greene, 1990). Here, the truncated normal distribution is adopted and its mean is a function of municipality effects and covariates. More specifically, we have

$$u_{it} \mid \alpha_i, z_{it}, \eta, \tau^2 \sim N^+(u_{it}, \tau^2) \quad (2)$$

$$u_{it} = \alpha_i + z_{it}\,\eta \quad (3)$$

where $N^+(a, b^2)$ denotes the normal distribution truncated at zero, whose associated normal has mean a and variance b. The above specification is similar than the one introduced by Schmidt et al. (2009), the difference consists in the possibility of modeling the inefficiency not only as a function of $\alpha = (\alpha_i, \ldots, \alpha_N)$ but also of covariates. In accordance with Schmidt et al. (2009), α_i is allowed to represent a process that spreads through spatial contagion, such as social and economic conditions. This process is frequently represented by priors that vary smoothly across space and, in several applications, it is assumed that α follows a conditional autoregressive distribution which depends on its neighbors. Therefore, this specification enables that the spatial structure is naturally imposed in the model (Besag, York and Mollié, 1991).

3.1 Inference procedure

Let $y_i = (y_{t1},..., y_{iT}, y_{N1},..., y_{NT})$ be a random sample of the logarithm of the outputs and $u = (u_{t1},..., u_{iT}, u_{N1},..., u_{NT})$ be the vector of unobserved inefficiencies. Assuming the model presented by Equations (1)-(3), the likelihood function is given by

$$p(y, u \mid r, z, \theta, \tau^2, \sigma^2, \eta) \propto (\sigma^2)^{-\frac{NT}{2}} \left(\exp\left[-\frac{1}{2\tau^2} \sum_{t=1}^{T} \sum_{i=1}^{N} \left(y_{it} - r_{it}\,\theta + u_{it} \right)^2 \right] \right) \times$$

$$\times (\tau^2)^{-\frac{NT}{2}} \left(\exp\left[-\frac{1}{2\tau^2} \sum_{t=1}^{T} \sum_{i=1}^{N} \left(u_{it} - \alpha_i - z_{it}\eta \right)^2 \right] \right) \times 1\left\{ u_{it} > 0 \right\}$$

Performing a Bayesian analysis, an important step is the prior distribution selection, in particular, in this case, the prior distribution of the random effects α. Since the data consists of observations made across municipalities, a certain spatial correlation is expected from these random effects and due to this geographical component, it is intuitive to think that the inefficiencies from neighboring municipalities share some common characteristics. For these reasons, as in Schmidt et al. (2009) and following (Besag, York and Mollié, 1991), we assume a conditional autoregressive (CAR) prior for α.

The conditional autoregressive (CAR) prior distribution is described as

$$p(\alpha \mid \psi^2) \propto \exp\left[-\frac{1}{2\psi^2} \sum_{t=1}^{T} \sum_{i=1}^{N} W_{ij} (\alpha_i - \alpha_j)^2 \right] \qquad (4)$$

and it is denoted by $\alpha \sim CAR\ (\psi^2)$. The matrix W is an adjacency matrix, it means that $W_{ij} = 1$ if municipality i shares a border with municipality j and $W_{ij} = 0$ otherwise. The distribution in Equation (4) is an improper joint distribution for α in a sense that it is possible to add a constant to all α_i without affecting it (Banerjee, Carlin and Gelfand, 2004). In order to guarantee that the posterior is proper, each sample from α obtained through Markov Chain Monte Carlo – MCMC (Gamerman and Lopes, 2006) methods is centered (Besag and Kooperberg, 1995; Gelfand and Sahu, 1999).

Thus far we have discussed the prior distribution of the latent random effects α. However, from a Bayesian perspective, the model specification is complete only after assigning a prior distribution to all unknowns in the model. Thus, it is remaining to talk about the prior distribution of the others parameters. Let υ the parametric vector $\upsilon=(\alpha, \sigma^2, \theta, \psi^2, \eta, \tau^2)$, and assume that all of its components are independent a priori. Hence, the joint density prior distribution for υ is given by

$$p(\upsilon) = \prod_{j=1}^{p} [p(\theta_j)]\, p(\sigma^2)\, p(\alpha \setminus \psi^2)\, p(\psi^2) \prod_{k=1}^{q} [p(\eta_k)]\, p(\tau^2) \quad (5)$$

In this paper, low a conjugate prior analysis. Therefore, considering the coefficient θ_j, $j=1,...,p$ and $\eta_k, k=1,..., q$ a normal prior distribution, $\varepsilon_{it} \sim N(\mu_0, \sigma_0^2)$, in which the hyperparameters $\mu_0= 0$ and $\sigma_0^2 = 100$ were specified. For the scale parameters $\upsilon = (\alpha, \sigma^2, \theta, \psi^2, \eta, \tau^2)$ σ^2 and τ^2 an inverse gamma prior distribution, $IG(\phi, \phi)$, with $\phi = 0.01$ was chosen. A special care must be taken when assigning the prior distribution for ψ^2 as this is a non-identifiable parameter in the sense of Dawid (1979), it is not recommended to be too uninformative (Besag and Kooperberg, 1995). For this reason, we adopt the same strategy as Schmidt et al. (2009), and an inverse gamma prior distribution, $IG(\phi_0, \phi_0)$, in which the mean is equal to the OLS variance estimate based on an independent stochastic frontier model and the variance is fixed.

4 EMPIRICAL ANALYSIS

4.1 The data

Three different databases were used, the school census from the National Institute for Educational Studies and Research "Anísio Teixeira" (Inep), SIDRA from the Brazilian Institute of Geography and Statistics (IBGE) and the National Treasury Secretariat database. From the first, we obtained the municipalities Basic Education Development Index (Ideb) for the students in 9th grade of lower secondary school, the infrastructure available in schools index and the pupil-teacher ratio. From the second, we collected the GDP of municipalities. From the last, we accessed the amount of Fundeb resources designated for each municipality.

The resultant data consists of a biennial sample over the period 2007-2017 from the 497 municipalities that integrate the Rio Grande do Sul state. However, because of a considerable number of missing data, a study based on the complete dataset was not possible. Hence, we opted to concentrate our work on the 34 municipalities of the Metropolitan area of Porto Alegre. This region is the 4th most populous in Brazil, concentrating more than 4 million inhabitants, and also is the 4th richest in the country. The problem of missing data occurs in all Brazilian States, which precludes the analysis at a national level.

In our analysis, the Ideb is specified as output. This index is a product of two variables that evaluate the education quality: the proficiency in Mathematics and Portuguese language, and the passing rate. In consequence, a municipality is considered as efficient not only by its grade but also by its capability of graduating students from lower secondary school. This choice is made because an educational system in which students systematically fail is not desirable. On the other hand, high approval rates are possibly correlated with insufficient learning from a sort of pupils.

As inputs of our model, we have the following variables: the pupil-teacher ratio, the infrastructure index and the Fundeb. The pupil-teacher ratio represents the labour input in our production function. The infrastructure index consists of the total resources available in the schools, it means, sports facilities, science and computer laboratories, libraries, internet access, projector and others. This variable, on its turn, serves as the physical capital. The Fundeb resources designated for each municipality was normalized by the total number of students registered according to the school census and it is considered as a variable for the public education spending.

Afonso and Aubyn (2006) state:

> We have considered the option of using education spending per student as an input. However, results would be hardly interpretable, as they would reflect both inefficiency and cost provision differences. For example, countries where teachers are better paid would tend to show up as inefficient, irrespective of the intrinsic performance of the education system.

Therefore, the choice for the Fundeb as an input and not the total education spending seems a good option since both variables are highly correlated and the first is not affected by differences in teacher remuneration for example. Table 1 summarizes the descriptive statistics of the 34 municipalities in the 6 years analyzed.

TABLE 1
Summary statistics

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Ideb	203	4.06	0.57	3.00	5.80
Pupil-teacher ratio	204	0.23	0.04	0.13	0.38
ln(Fundeb)	204	7.07	0.36	6.50	8.27
Infrastructure	204	7.25	0.87	4.28	8.89
Ln(GDP)	204	10.39	0.59	8.95	12.8

Authors' elaboration.

4.2 Results

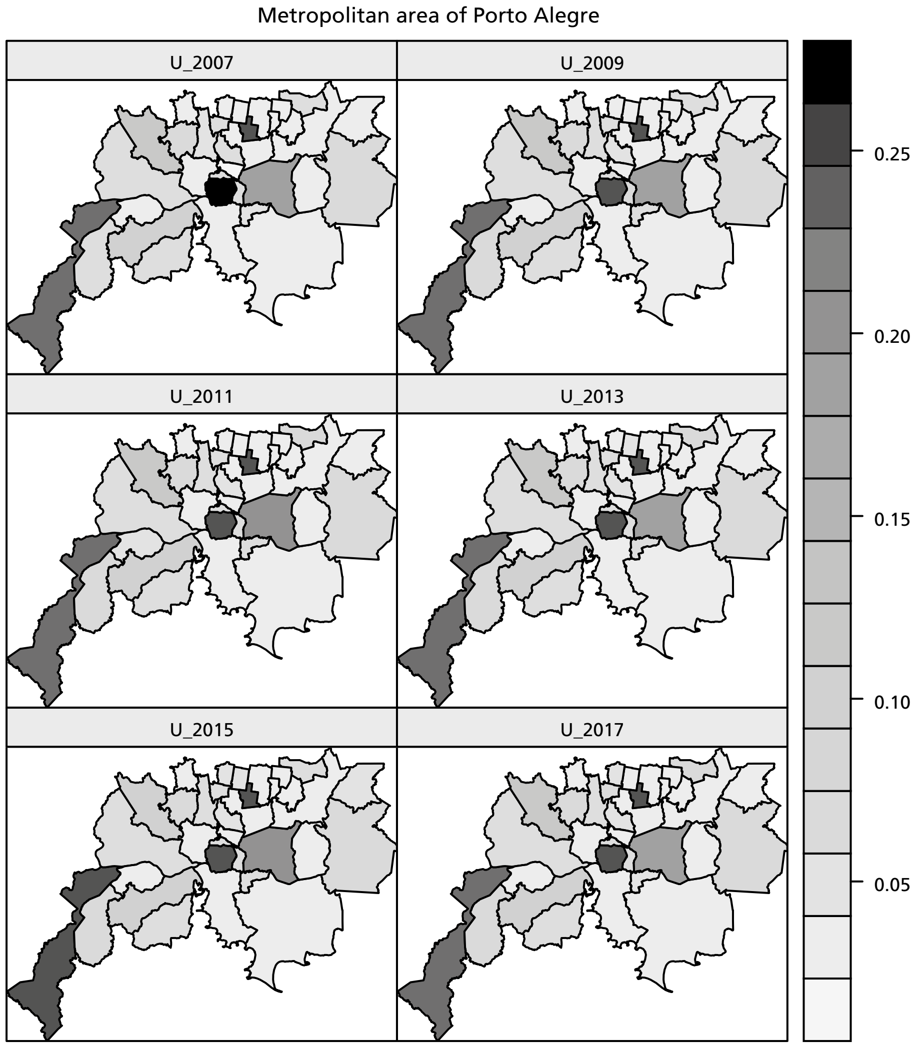
Table 2 summarizes the results obtained from the inference process. It presents the posterior means and the 95% high posterior density credibility interval for the parameters considered on the model proposed in section 3. To this end, 50000 iterations from a MCMC scheme were drawn and the first 10000 were discarded as a burn-in period. In order to reduce the autocorrelation between successive values of the simulated chain, only every 4th values of the chain were stored, resulting on 1000 draws. Figure 1 illustrates the inefficiencies u_{it} for the municipalities located in the Metropolitan area of Porto Alegre over the period 2007-2017. As it is a specific group of 34 municipalities, interpretations at the national level should be done with caution. Analyzing the figure, there is almost no variation on the inefficiencies, in other words, regions with higher levels of inefficiency are not improving their investment policy along the years and a feasible explanation for that is the lack of incentives for better practices due to the actual legislation. Considering the spatial effects, most of them were not significant, suggesting that our prior belief about the inefficiencies as an economic process that spreads through spatial contagion is not being captured by.

TABLE 2
Estimation results for the parameters based on a sample of size of 1000 from the posterior distribution

Parameters	Mean	Interval
θ_0 (Intercept)	3.1129	(0.9889,5.2508)
θ_1 (Pupil-teacher ratio)	1.3251	(0.9066,1.7433)
θ_2 (Fundeb)	0.4473	(0.2626,0.6516)
θ_3 (Infrastructure index)	-0.2865	(-0.7675,0.1902)
σ^2	0.1683	(0.1371,0.2115)
η^1 (GDP)	.0099	(0.0076,0.0134)
τ^2	0.0002	(0.0001,0.0004)

Authors' elaboration.

FIGURE 1
Evolution of the inefficiencies over the period 2007-2017



Authors' elaboration.

From table 2, it is possible to observe that from the three inputs, only the infrastructure available in schools index is not significant since its credibility interval contains the 0. The literature is not conclusive about this variable as regards efficiency estimation in education. As reported by Glewwe et al. (2011), apart from basic goods like electricity, table or chairs, there is not a definite understanding about the positive impact of other goods on pupils development.

Looking for variables which contemplate teachers characteristic, there is also not a definite understanding. In this work, we used the pupil-teacher ratio as long as it is broadly applied as input in similar contexts than ours (Afonso and Aubyn, 2006; Kirjavainen, 2012; Agasisti, 2013). The estimates point that this ratio has a positive and significant coefficient, it means that the supply of teachers contributes to a better educational system. De Witte and López-Torres (2017) interprets this result, explaining that larger supplies enable more individualized work with students.

The Fundeb coefficient indicates that this is an effective instrument for advances in the public schools located in Metropolitan area of Porto Alegre. This is a relevant result once the fund aims to guarantee a minimum investment in education and due to the actual discussion about the theme. The Fundeb's validity expires at December 2020 and a debate about its effectiveness and alternatives redistribution criteria is a point of interest.

The main hypothesis of this paper says that wealthy municipalities are less efficient in the allocation of their resources due to the legislation and mechanisms introduced in section 2.2. To that end, we extended the model proposed Schmidt et al. (2009) to accommodate the GDP as a covariate that explains the inefficiency. From table 2, we observe that this variable has a positive relation with the inefficiency and it is statistically significant. This evidence endorses our hypothesis and it is in accordance with Monteiro (2015) who concluded that Brazilian oil producing municipalities benefited by revenues from royalties are less efficient than others with similar characteristics.

The previous points corroborate with the idea of redistribution criteria based not only on students profile and the number of registrations in the public network, but also on the economic capacity of the municipalities. These points also demonstrate that the outcomes obtained by Afonso and Aubyn (2006), Fonchamnyo and Sama (2016) and Cordero, Santín and Simancas (2017) about the relation between GDP and inefficiency in a country level might not be observed when we focus on municipalities, in particular, when we have a rigid legislation about the amount that must be invested in education.

5 CONCLUSION

A common idea in Brazilian public debate is that advances in educational quality are directly proportional to the amount of investment in the area. Although this argumentation might be appealing, the education economics literature presents some evidences in a different direction (Hanushek and Luque, 2003; Glewwe et al., 2011; Monteiro, 2015), exposing the necessity to a well designed public policy and rigorous evaluations about its effectiveness. Towards the current economic scenario and the serious fiscal crisis that

Brazil is facing, a particular topic of interesting rises from the discussions: efficiency in education management, specially, in education spendings.

Therefore, this paper contributes to the literature investigating the relation between inefficiency in the Brazilian education system and municipal wealth, discussing how the actual legislation possibly influences it. We underline the actual legislation because it imposes rigid regulations that disregards the economic capacity of each municipality and does not introduces incentives for efficient policies which is of great importance since local governments have limited budgets.

A stochastic frontier model was applied to a panel dataset from the Metropolitan area of Porto Alegre municipalities over the period 2007-2017 and the results indicated that the GDP per capita has a positive effect on inefficiencies, suggesting that richer municipalities are less efficient in allocating their resources and corroborating to our main hypothesis. Two other results should be highlighted. The positive impact of Fundeb on Ideb combined with the positive effect of GDP on inefficiencies, points to an alternative criteria to the fund redistribution based on the economic capacity of the municipalities. In addition, no significant improvements on efficiencies were observed over the period under analysis, indicating a lack of incentives. For future research, this model can be used for a larger number of municipalities, covering other regions of the country. However, to do this it would be necessary to use imputation or interpolation methodologies due to the problem of missing observations for many municipalities.

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