Pró-Reitoria Acadêmica
Escola de Gestão e Negócios
Programa de Pós-Graduação Stricto Sensu em Economia

EDUCATION ESSAYS: DETERMINANTS OF SCHOOL SUCCESS

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Brasília - DF
2019

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Thesis presented to the *Stricto Sensu* Postgraduate Program in Economics of the Catholic University of Brasília, as a partial requirement to obtain a PhD in Economics.

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Brasília
2019

A474c Alves, Fabiana de Assis.
Education essays: determinants of school success / Fabiana de Assis Alves – 2019.
66 p.: il.; 30 cm

Thesis (Doctorate) – Universidade Católica de Brasília, 2019.
Supervisor: Prof. PhD. Osvaldo Candido da Silva Filho

1. School effect. 2. Peer effect. 3. Educational funding. 4. Quality of the education. 5. Multilevel model. I. Silva Filho, Osvaldo Candido da, superv. II. Title.

UDC 330

Tese de autoria de Fabiana de Assis Alves, intitulada *"Ensaios em Educação: Determinantes do Sucesso Escolar"*, requisito parcial para obtenção do grau de Doutora em Economia, defendida e aprovada, em 27 de fevereiro de 2019, pela banca examinadora constituída por:

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Brasília-DF
2019

To my husband, Marcus, and to my loved parents, brothers, sister, and nephews.

ACKNOWLEDGEMENTS

To God for giving me strength to overcome all the difficulties of this arduous stage. Thank you, Lord, for putting wonderful people on my way and helping me get here.

To my husband, Marcus, for the affection and emotional support.

To my dear parents, brothers and sister, brother-in-law and sister-in-law, and nephews, who even from a distance made themselves present through encouragement, love, and understanding.

To my supervisor, Professor Osvaldo Candido, for the patience, support and shared knowledge. His tranquillity and serenity helped me through many moments of despair.

To the professors of the Department of Economics of UCB, for the teachings, dedication and friendship.

To all employees of UCB, especially Maísa and Luana, for the kindness and support given throughout the course.

To the colleagues and friends who participated in this journey, especially to Rubiane, Jussara, Daniel, Angelo and others who shared anguish, despair and lists of exercises throughout these four years. Thank you for the moments of relaxation, friendship and strength in difficult times.

To the members of the examining board, professors Augusto Marques de Castro Oliveira, Geraldo Andrade da Silva Filho, Luciene Torres de Mello Pereira, and Philipp Ehrl, for the availability and contributions to the improvement of this work.

To the National Institute of Studies and Research in Education Anísio Teixeira - INEP, for offering the necessary conditions to achieve one more goal. To my work colleagues, in special to Rafaela, Marcelo, and Mariano, for teaching me the details of educational financing and data structure of SIOPE.

To the Coordination for the Improvement of Higher Education Personnel - CAPES, for the opportunity to be a Fellow.

To the Federal District Research Support Foundation (FAPDF) for financial supporting the projects: Factors Affecting the School Performance in Brazil: Degrees of Substitution and Complementarity (FAPDF - 193.000.217/2014); and Educational Indicators and the Impact of Investments in the Educational System in the Brazilian Municipalities (INDEDU - FAPDF - 193.000.966/2015).

I would also thank all the people that directly and indirectly helped me to complete this achievement.

ABSTRACT

Reference: Alves, Fabiana de Assis. **Essays on Education: Determinants of school success.** 2019. 66 pp. Thesis (Doctorate in Economics) - Universidade Católica de Brasília, Brasília, 2019.

The purpose of this thesis is to identify some factors that contribute to the quality of education. In the first essay, the data from the last three editions of the Programme for International Student Assessment (PISA) are used to assess the effect of Latin American schools on student performance and to identify the factors that contribute to their performance. Using the multilevel model as an empirical strategy, the results found indicate that the family history, the characteristics of the student and the profile of the school community (peer effect) are fundamental to explain student performance. Regarding school inputs, the most important determinants were the disciplinary climate in the classroom and the existence and adequacy of pedagogical resources. In addition, the use of a multilevel approach is extremely important, since a considerable part of the variation in student performance is explained by the differences between schools. The second essay aims to verify if public spending on education by Brazilian municipalities contributes to improving the quality of schools in the municipal school system. The Basic Education Development Index (IDEB) was used as a proxy for the quality of schools. Municipalities' expenses, derived from SIOPE were broken down into current expenses and capital expenditures. In this essay, the multilevel model was also used as an empirical strategy, applied to biennial data from 2009 to 2017. All adjusted specifications had control variables that depict characteristics of schools and the municipal network. The results provide evidence that both current and capital spending on education have positive effects on the IDEB. Although these effects were significant in all settings, the magnitudes observed were relatively small. This reinforces the need for a more detailed assessment of the destination and effectiveness of the resources invested, especially in a country with considerably limited financial resources.

Keywords: School effect, peer effect, educational funding, quality of the education and multilevel model.

RESUMO

Referência: Alves, Fabiana de Assis. **Ensaios em Educação: Determinantes do sucesso escolar**. 2019. 66 pp. Tese (Doutorado em Economia) – Universidade Católica de Brasília, Brasília, 2019.

O objetivo desta tese é identificar alguns fatores que contribuem para a qualidade da educação. No primeiro ensaio são utilizados os dados das últimas três edições do Programa para Avaliação Internacional de Estudantes (PISA) para avaliar o efeito das escolas latino-americanas sobre o desempenho dos alunos e identificar os fatores que contribuem para o seu desempenho. Utilizando como estratégia empírica o modelo multinível, os resultados encontrados indicam que o histórico familiar, as características do aluno, e o perfil da comunidade escolar (efeito de pares) são fundamentais para explicar o desempenho dos alunos. Quanto aos insumos escolares, os determinantes que mais se destacaram foram o clima disciplinar em sala de aula e a existência e adequação de recursos pedagógicos. Além disso, o uso de uma abordagem multinível é de extrema importância, uma vez que uma parte considerável da variação no desempenho dos alunos é explicada pelas diferenças entre as escolas. O segundo ensaio tem como objetivo verificar se os gastos públicos em educação pelos municípios brasileiros contribuem para melhorar a qualidade das escolas da rede municipal de ensino. O Índice de Desenvolvimento da Educação Básica (IDEB) foi utilizado como *proxy* para a qualidade das escolas. Os gastos dos municípios, provenientes do SIOPE, foram desagregados em despesas correntes e despesas de capital. Neste ensaio também foi utilizado o modelo multinível como estratégia empírica, aplicado a dados bienais de 2009 a 2017. Todas as especificações ajustadas contaram com variáveis de controle que retratam características das escolas e da rede municipal. Os resultados trazem evidências de que os gastos com educação, tanto em despesas correntes quanto em despesas de capital, têm efeitos positivos sobre o IDEB. Apesar desses efeitos serem significativos em todos os ajustes, as magnitudes observadas foram relativamente pequenas. Isso reforça a necessidade de uma avaliação mais detalhada sobre o destino e a efetividade dos recursos aplicados, especialmente em um país com recursos financeiros consideravelmente limitados.

Palavras-chave: Efeito Escola, Efeito de Pares, Financiamento Educacional, Qualidade da Educação e Modelo Multinível.

RÉSUMÉ

Référence: Alves, Fabiana de Assis. **Essais sur l'éducation: Déterminants de la réussite scolaire**. 2019. 66 pp. Thèse (Doctorat en économie) – Universidade Católica de Brasília, Brasília, 2019.

Le but de cette thèse est d'identifier certains facteurs qui contribuent à la qualité de l'éducation. Dans le premier essai, les données des trois dernières éditions du Programme international d'évaluation des étudiants (PISA) sont utilisées pour évaluer l'effet des écoles latino-américaines sur les performances des élèves et pour identifier les facteurs qui contribuent à leurs performances. En utilisant le modèle à plusieurs niveaux comme stratégie empirique, les résultats obtenus indiquent que les antécédents familiaux, les caractéristiques de l'élève et le profil de la communauté scolaire (effet de pairs) sont fondamentaux pour expliquer le rendement de l'élève. En ce qui concerne les intrants scolaires, les déterminants les plus importants étaient le climat de discipline dans la classe et l'existence et le caractère adéquat des ressources pédagogiques. En outre, l'utilisation d'une approche à plusieurs niveaux est extrêmement importante, car une partie considérable de la variation des performances des élèves s'explique par les différences entre les écoles. Le deuxième essai vise à vérifier si les dépenses publiques consacrées à l'éducation par les municipalités brésiliennes contribuent à améliorer la qualité des écoles dans le système scolaire municipal. L'indice de développement de l'éducation de base (IDEB) a été utilisé comme indicateur indirect de la qualité des écoles. Les dépenses des municipalités, dérivées de SIOPE, ont été désagrégées en dépenses courantes et dépenses en capital. Dans cet essai, le modèle à plusieurs niveaux a également été utilisé comme stratégie empirique, appliquée aux données biennales de 2009 à 2017. Toutes les spécifications ajustées comportaient des variables de contrôle décrivant les caractéristiques des écoles et du réseau municipal. Les résultats démontrent que les dépenses d'éducation, tant les dépenses courantes que les dépenses en capital, ont des effets positifs sur l'IDEB. Bien que ces effets aient été significatifs dans tous les contextes, les magnitudes observées étaient relativement faibles. Cela renforce la nécessité d'une évaluation plus détaillée du destin et de l'efficacité des ressources investies, en particulier dans un pays avec des ressources financières considérablement limitées.

Mots clés: effet des écoles, effet de pairs, financement de l'éducation, qualité de l'éducation et modèle à plusieurs niveaux

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1. INTRODUCTION

The economic literature reports robust evidence that education has positive effects on economic growth. Mincer (1974), Mankiw et al. (1992), and Ferreira et al. (2003) are some examples of studies that found a positive relationship between measures of schooling and economic growth. As the quality of education is one of the pillars for sustainable economic development and therefore a recurrent demand of society, governments should properly direct efforts and resources to this area.

Hanushek et al. (2008) and Hanushek and Woessmann (2008 and 2012) have improved the discussion on the impact of education on economic development. For these authors, the average years of schooling, one of the main proxies for measuring human capital, is quite fragile. This is because a year of schooling in different educational systems (Peru and Singapore, for example) can provide a different knowledge and skills. They point out that the cognitive abilities of the population are more strongly related to individual gains, income distribution, and economic growth than to the number of years of study. Thus, besides guaranteeing the access and permanence of the students in the school, it is fundamental that the education system provides a good quality of learning.

In recent decades, Latin American countries have made important progress in covering educational systems. However, the learning of its students measured in international assessments has not been satisfactory, which raises policies focused on the most relevant factors for the increase of students' cognitive abilities. In this context, the first study aims to evaluate the effect of Latino schools on student achievement and identify factors that contribute significantly to their improvement. For this purpose, data from the Programme for International Student Assessment (PISA) for the years 2009, 2012 and 2015 were used for seven Latin American countries, namely Brazil, Chile, Colombia, Costa Rica, Mexico, Peru, and Uruguay.

The multilevel model was used as an empirical strategy. This methodology has gained prominence in studies of this nature, since it considers the hierarchical structure present in the data of educational evaluations and allows quantifying the portion of the variability in the students' results that is due to the differences between the schools (school effect).

The results of this first study showed that family background, student characteristics, and school community profile (peer effect) are key to explaining academic success. Regarding school inputs, the most important determinants were the disciplinary climate in the classroom and the existence and adequacy of pedagogical resources. In addition, it was found that the use of a multilevel approach is fundamental for Latin countries, since a considerable portion of the

variation in students' income is explained by differences between schools. The models showed that these differences are due not only to school inputs, but also to strong socioeconomic segmentation.

The second study focuses on the Brazilian context and aims to assess whether investments in education in municipalities affect the quality of municipal schools. In recent years, Brazil has considerably expanded resources for education. According to OECD data for the year 2015, total direct and indirect expenditures with education from primary education to higher education, investments in Brazil reached 5.5% of GDP, a percentage higher than the average of the OECD member countries, which was 4.5%. However, despite this significant increase in investments in education, the average expenditure per student of primary and secondary education in Brazil is around 40% of the expenditure per student of the OECD member countries, according to OECD (2018).

In order to construct the municipal investment indicators in education, data from the Information System on Public Budgets in Education (SIOPE) were used. These indicators represent the expenditures of municipalities with current and capital expending. The Basic Education Development Index (IDEB) of municipal schools that attend the primary school was used to describe the quality of schools. The multilevel model applied to biannual data between 2009 and 2017 was used as empirical strategy. All adjusted specifications relied on control variables that portrayed characteristics of schools and the municipal network. The results show that both current and capital expenditure on education has positive effects on the IDEB. Although these effects were significant in all fitted models, the magnitudes observed were relatively small. These findings indicate that the simple increase in education spending will not be enough to overcome the educational delay observed in the country. It is essential the adoption of a more detailed monitoring of the management of financial resources and an evaluation of the effectiveness of these expenditures. In addition, the articulation and commitment of the institutions responsible for the education system can contribute in the conversion of these financial resources to improve the quality of education.

2. SCHOLL EFFECT AND STUDENT PERFORMANCE: A LATIN AMERICAN ASSESSMENT FROM PISA

2.1 Introduction

The literature on economic development highlights the close relationship between a country's economic growth and the educational level of its population. For instance, Mincer (1974), Mankiw *et al.* (1992) and Ferreira *et al.* (2004) find a positive relationship between education and economic growth. Therefore, these authors suggest that knowledge may enhance labour force, affecting the productivity of a country, a region, or a firm.

As specified by Hanushek *et al.* (2008) and Hanushek and Woessmann (2012), the empirical debate warns that the use of years of schooling as a proxy for measuring human capital is quite fragile, since one year of schooling in different educational systems (Peru and Singapore, for example) can provide a distinct advantage in skills. They show that the cognitive abilities of the population are more strongly related to individual gains, income distribution, and economic growth than to years of schooling. Thus, it is imperative not only to guarantee regular school access and permanence, but an educational system that provides learning quality.

Latin American countries have improved their educational attainment in the last decades. Such advances can be observed in the indicators of 'access to school'. With increasing attendance and permanence of students in the educational system, these countries have been able to raise the average years of schooling of their population. However, the measures of students' performance provided by international assessments are quite disappointing. Despite those breakthroughs, the cognitive skills of Latin American students participating in international testing remain far behind the skills of students from developed countries. Hanushek *et al.* (2012), by comparing six groups of countries (East Asia and India, Central Europe, Organisation for Economic Co-operation and Development (OECD), Latin America, the Middle East and North Africa, and Sub-Saharan Africa), show that the average performance of Latin American students is only slightly superior to that of sub-Saharan Africa. This suggests that policies for raising students' learning quality could be of great impact in this field.

These findings about Latin American countries seem consistent with their low productivity, Gross Domestic Product (GDP) per capita, Human Development Index (HDI), and other economic and social indicators. If on the one hand cognitive abilities have a positive impact on GDP, on the other hand countries with low productive capacity have few resources devoted to education. As a solution to this vicious cycle, governments should optimize public

expenditures in education, which depends on the correct identification of the most relevant factors for an efficient educational system.

Data from large-scale educational assessments, such as PISA, are becoming increasingly important to understand economic, educational and social phenomena. PISA evaluates Reading, Scientific literacy, and Mathematics skills. In addition, it is common to apply contextual questionnaires that portray characteristics of students, families and schools. Assuming that the students' performance is a good indicator for the educational system quality and that there are data about families and schools, one can identify some factors that explain students' cognitive abilities.

Several studies have highlighted the characteristics of the student and his/her family background as the main determinants of schooling success. Regarding the role of the school, there is no consensus. Coleman et al. (1966) describe, in one of the first and most relevant studies on the subject, that students' test results to assess verbal and non-verbal skills are related to the characteristics of the students, the families, the schools and the teachers. They conclude that the differences in educational output would be better explained through socio-economic variables than by school related characteristics. Subsequently Hanushek *et al.* (1996), from a broad review of previous studies and new empirical analyses, conclude that articles that indicate a positive and significant relationship between educational inputs and student performance use data with such a high degree of aggregation that it eventually inflates the estimated coefficient. For studies in which data have low level of aggregation, evidence of any positive relationship between the inputs and the performance (if statistically significant) are much smaller. In contrast to these two studies, Hedges *et al.* (1994), Greenwald *et al.* (1996a, 1996b), and Dewey *et al.* (2000) find significant effect of school related variables on student productivity.

Taking into account the aforementioned literature, the main objective of this work is to assess the determinants of the Latin American students' performance. The variables supposed to affect students' performance are grouped into three main dimensions: individual characteristics, family background, and school facilities. The data used for the empirical analysis comes from the last three available editions of PISA (2009, 2012, and 2015) for seven Latin American countries.

A multilevel approach is used to perform the empirical analysis. This method has become widely used as an empirical strategy when the data available have a hierarchical structure. That is, the observations have multiple levels of aggregation. An interesting feature of this modelling is the possibility to identify micro-level effects (from individual characteristics) and macro-level effects (from differences among aggregating groups). For this

work, two hierarchical levels are considered: student level and school level. Thus, the effects of students' characteristics and differences among schools (school effect) on the students' performance on PISA can be estimated.

Hanchane and Mostafa (2012) warn that endogeneity bias may arise in estimating multi-level models for educational production functions and propose a robust methodology that allows to overcome them. The authors suggest that the main source of endogeneity comes from the subject level (school level), that is, when individuals explanatory variables included in the model are correlated with the school level random component due to an omitted variable problem. In this sense, their method consists of including the peer effect in the estimation of the multilevel model, *i.e.*, include the students' characteristics aggregated by school. Using PISA 2003 data, the authors find a significant endogeneity for two out of three countries in the sample.

Another rationale in considering this peer effect is that behaviour, as well as student performance, are also influenced by the socio-economic status and other characteristics of those individuals surrounding the student. That is, the cultural and socio-economic status of the neighbourhood or community (or their peers), to which the student belongs, is important in determining his/her behaviour and academic performance. Caldas and Bankston (1997) and Van Ewijk and Sleegers (2010) show some evidence of the importance of the inclusion of peer effects variables for student performance assessments. In our empirical analysis for all countries, the inclusion of this peer effect is statistically significant.

This paper is organized as follows. Section 2.2 is devoted to the methodological approach with a brief discussion of the International Student Assessment Program (PISA) and the indicators used to explain the observed variation in student performance. A description of the multilevel modelling technique is also presented in this section. The models set for each country and for each PISA edition, as well as a discussion on the research results can be found in section 2.3. Section 2.4 is dedicated to the conclusions of the study.

2.2 Data and empirical procedures

The educational services provision, like other services in economics, results from the combination of production factors. The technology involved in this process can be very complex and subject to random shocks coming from educational policies, economic conditions and even political conflicts, which may affect the educational system quality in a country or region.

The concept of production function, which stems from fundamentals of Microeconomics, has been widely used in education since Coleman *et al.* (1966). An educational production function can be formulated as a combination of several factors that maximize the quality of the transmission of knowledge to students. This function can be expressed through a model that outlines the relationship between the educational inputs and the students' attainment (output). Therefore, indicators such as students' performance scores, years of schooling, literacy, grade repetition, success in the labour market, approval in selection processes, among others, can be used for this purpose.

Regarding inputs, one can explore several factors that can be grouped into three large dimensions:

i. Factors related to the individual (*I*): gender, age, interest or enthusiasm for the school and the subjects studied, time spent studying, interest in Reading and Information and Communication Technology (ICT), school dropout, etc.
ii. Factors related to the student's family background (*B*): economic conditions of the student's family, income or occupation of the parents, social stratum to which the family belongs, parental education, possession of household goods, structure and household situation, among others.
iii. Factors related to school facilities (*S*): physical infrastructure, existence of pedagogical resources such as teaching materials, reading rooms, libraries, computer and science laboratories, the student-to-teacher ratio, the educational level of the teachers, the commitment and dedication of the employees, the autonomy to manage the human and financial resources, etc.

In this way, an educational production function can generically be represented as

$$R = f(I, B, S)$$

where *R*, a student's performance measurement, is a function of student related factors: individual (*I*), family background (*B*) and school facilities (*S*).

2.2.1 PISA assessment data

The Programme for International Student Assessment (PISA) is a large-scale educational evaluation coordinated by the Organization for Economic Co-operation and Development (OECD), held every three years since 2000. The population target is defined as 15-year-old students near the end of their compulsory education.

The assessment focuses on three cognitive areas: Science, Mathematics, and Reading. Within each edition, special focus is placed on one of the areas. Reading was highlighted in the

first edition in 2000 and again in 2009. In the 2003 and 2012 editions focus was placed on Mathematics and, in 2006 and 2015, the focus was on Sciences. In addition to the tests that assess students' proficiency, context questionnaires are applied bringing aspects related to the student, the family, and the school. These questionnaires are used in the formulation of demographic, social, and educational indicators that can be used towards a better understanding of the differences in performance among students.

For this work, the data for Latin American students in three editions of PISA are used: 2009, 2012 and 2015. Since some indicators are available only for the area focused in the given edition, only these data are used, *i.e.*, in 2009 Reading, 2012 Mathematics and 2015 Science. In order to assess the students' performance, five indexes based on the student's questionnaire are used[1]. They represent student characteristics, family background and the student's perception of the disciplinary climate in the classroom. Additionally, school facility indicators, extracted from the questionnaire answered by the dean of the school (or someone nominated by him), are included. A summary of these indicators can be seen in Table 2.1.

Table 2.1 - Summary of selected Pisa Indicators

Indicator	Description	Year	Dimension
ESCS	Index of economic, social, and cultural status.	2009/2012/2015	Family
AGE	Age of student	2009/2012/2015	
Female	Genre: (1) Female (0) Male	2009/2012/2015	Student
REPEAT	Dummy variable that indicates student grade retention	2009/2012/2015	
DISCLIMA	Perception of the student about the disciplinary climate in the classroom	2009/2012	
DISCLISCI	Perception of the student about the disciplinary climate in the science classes	2015	
STRATIO	Ratio between the number of students and teachers in the school	2009/2012/2015	
SCMATEDU	Educational Resources Index.	2009/2012	School
SCIERES	Resources availability index for Sciences	2015	
RESPRES	School autonomy index for resource allocation	2009/2012/21015	
PROPQUAL	Percentage of teachers with an ISCED 5A qualification	2009/2012	
PROAT5AM	Percentage of teachers with MSc.	2015	
TCSHORT	Index on the teacher deficit.	2009/2012	
STAFFSHORT	Index on the deficit of teachers and assistants	2015	

The ESCS indicator is built on information about schooling and parental occupation, household goods, and educational and cultural resources. It is one of the most used proxy for

[1] Several other indicators were used, but most of them were not available for the entire sample. Thus, their inclusion reduced dramatically the sample size and others were not statistically significant. These indicators were excluded from the analysis and will not be reported but are available upon request.

the family background. The REPEAT, AGE, and FEMALE variables refer to student characteristics. REPEAT is considered a proxy for student performance in prior periods.

Concerning school facility variables, the indicators are: availability of pedagogical resources (SCMATEDU and SCIERES), disciplinary climate in the classroom (DISCLIMA and DISCLISCI), student-to-teacher ratio (STRATIO), teachers' educational degree (PROPQUAL and PROAT5M), teacher and teaching staff shortage (TCSHORT and STAFFSHORT), and institutional autonomy regarding resource allocation (RESPRES).

Additionally, averaged (by school) versions of REPEAT and ESCS variables (MESCS and MREPEAT) are included in the model. The rationale is twofold: to evaluate the peer effect concerning to socioeconomic status of the school (or community profile surrounding the school) and to solve endogeneity problems. The latter will be discussed further.

The sample used in the empirical analysis comprises the indicators summarized in Table 1 for the seven Latin American countries - Brazil, Chile, Colombia, Costa Rica, Mexico, Peru, and Uruguay - that engaged on the PISA assessment in 2009, 2012, and 2015. The indicators used here were kept in its original scale. Thus, for more details about the computing, interpretation and scales of them, the reading of the PISA Technical Reports is recommended[2].

2.2.2 Multilevel Models

Multilevel or hierarchical models are suitable for analysing data that present a hierarchical or nested structure (*i.e.*, individuals or groups are ranked or aggregated by location, status, authority, etc.). In most large-scale educational assessments, this structure is observed, since students are allocated to classes and classes are organized in schools.

For Rasbash *et al.* (2017), the use of Multiple Regression (OLS) models on hierarchical data is inadequate because it does not quantify the variation between the classes and the schools. The multilevel analysis improves the accuracy of the estimators related to individuals, allowing the researcher to better understand the effects of the hierarchy and to elaborate more complex questions. In addition, it prevents underestimation of the coefficients standard errors, since it takes into account other source of variations.

From the PISA data, it can be identified two hierarchical levels[3] - student and school - which allow us to represent the model as follows

[2] See: *http://www.oecd.org/pisa/publications/*.

[3] The PISA reference population is composed of 15-year-old students who are enrolled from the 7th grade. The participants of a given school may be either in the same class, in different classes of the same teaching stage, or they may belong to different stages. In this way, the data structure allows the inclusion of only two levels (students and schools).

Level 1– Student $y_{ij} = \beta_{0j} + \beta X_{ij} + \varepsilon_{ij}$

Level 2 – School $\beta_{0j} = c + \gamma K_j + \delta \bar{X}_{.j} + u_j,$ or

$$y_{ij} = \mathrm{c} + \beta X_{ij} + \gamma K_j + \delta \bar{X}_{.j} + u_j + \varepsilon_{ij} \quad (2.1)$$

where y_{ij} is the score on PISA (Science, Mathematics or Reading) of the student i from school j ; X_{ij} are the student i from school j variables; $\bar{X}_{.j}$ is the peer effect variables, *i.e.*, students' family background and individual characteristics averaged by school; K_j school j variables, and ε_{ij} and u_j are random components related to the measurement level (Level 1 - Student) and the subject level (Level 2 - School), respectively. The main difference between the specification in 2.1 and the Multiple Regression is the presence of these two random components. The intercept c is the same for all students and schools. All these variables are summarized in Section 2.1.

The standard hypotheses to make inference from 2.1 are:

1. The random components are uncorrelated and both independent and normally distributed

$$\begin{pmatrix} \varepsilon \\ u \end{pmatrix} \xrightarrow{i.i.d} \mathcal{N}\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_\varepsilon^2 & 0 \\ 0 & \sigma_u^2 \end{pmatrix} \right).$$

2. The random components are uncorrelated with the explanatory variables, *i.e.*, $Z = [X\ K\ \bar{X}]$ and $\epsilon = [\varepsilon\ u]$, $cov(Z, \epsilon) = 0$

From the hypothesis above and considering $Z = [1\ X\ K\ \bar{X}]$, $\theta = [c\ \beta\ \gamma\ \delta]'$, $\sigma = [\sigma_\varepsilon^2\ \sigma_u^2]$ and $V = var(y)$, the log-likelihood function for estimating the parameters of the equation 2.1 can be represented as follows

$$\ell(\theta, \sigma | y, Z) \propto \frac{1}{2}\left\{\log|\mathrm{V}(\sigma)| + (Y - Z\theta)'\big(\mathrm{V}(\sigma)\big)^{-1}(Y - Z\theta)\right\}. \quad (2.2)$$

Thus, the Restrict Maximum Likelihood Estimator (RMLE) is

$$(\hat{\theta}, \hat{\sigma}) = \underset{\theta,\sigma}{\operatorname{argmax}}(\ell(\theta, \sigma | y, Z))^4.$$

If the hypothesis 2 does not hold for at least one explanatory variable, the endogeneity problem arises. According to Hanchane and Mostafa (2012), when modelling student performance determinants, the researcher has to take into account the endogeneity that comes

[4] For details on parameter estimation of multilevel models see De Leeuw *et al.* (2008).

from school level. The authors argue that this problem arises from the possible correlation among students' individual characteristics and omitted school related variables. To deal with this, the authors suggest the inclusion of the so-called "peer effect". The rationale is to proxy the school community profile, which is considered relevant in determining the school performance according to findings in the literature. This justify the inclusion of the variables in $\bar{X}$.

It is worthy to notice that in the model individuals (students) of different groups (schools) are independent and students within the same schools share the same u_j, thus correlated. Therefore, since the variance of $V = var(\varepsilon_{ij}) + var(u_j)$ and the covariance between two students i and i' $(i \neq i')$ in the school j is $(y_{ij}, y_{i'j}) = var(u_j) = \sigma_u^2$, the correlation between two students from the same school is

$$\rho = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_\varepsilon^2}.$$

This allows one to evaluate between-school and within-school effects. In other words, it is possible to identify the school effect on the student performance measure, *i.e.*, the higher is ρ the higher is the impact of the difference among the schools on the student performance[5]. The reason is that ρ (also referred as intraclass correlation) indicates the fraction of the students' performance variance explained by the grouping structure in the population.

2.3 Results

Tables 2.2 to 2.55 show the main results for the empirical analysis. Tables 2.2 to 2.4 show the parameter estimates for the specification in 2.1, with and without peer effect (including and excluding the vector of variables $\bar{X}$), for each country and PISA edition under analysis. Table 2.5 shows the variance decomposition, *i.e.*, between-school, within-school and overall. On this table it is also included results for a benchmark model which is merely a null model (only a constant is included in the model).

It is noticeable from the empirical results that the preferred model is the one which includes the peer effect variables. On all PISA editions, the MESCS variable is statistically significant for all assessed countries, while the MREPEAT variable is statistically significant for almost all. Some coefficients associated to school group, which are significant in the model without the peer effect, become not significant when the peer effect is taken into account. In the sense of Hanchane and Mostafa (2012), this result suggests an endogeneity problem, so the

[5] Note that $\rho \neq 0$ implies the Ordinary Least Squares (OLS) estimator for 2.1 is biased and inconsistent.

variables MESCS and MREPEAT should be included in the model. The Log-likelihood Ratio (LR) test also suggests that the preferred model is the one including peer effects variables.

Additionally, one can highlight that the positive value for the coefficient of MESCS indicates that the higher the socio-economic status of the school the higher the student performance. That is, if the student is located in a school where the cultural and socio-economic status of the community surrounding him/her is high, the chances of a good performance in the PISA assessment increase. In the same way, MREPEAT presents a negative coefficient which indicates that the higher the retention rate in the school, the lower the student performance. In brief, exposing the student to a better environment (high cultural and socio-economic levels community and "better" peers within the school) improves the student performance.

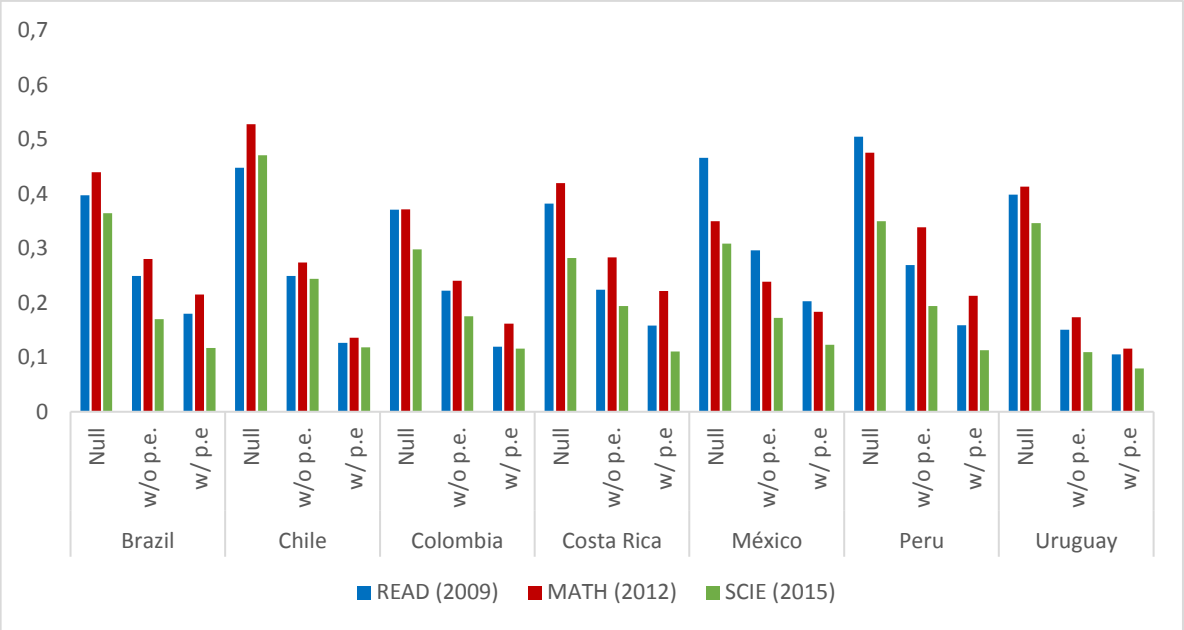
The discussion that follows is based only on the model with peer effects since this is the preferred according to the tests.

2.3.1 School effect

First, it is necessary to evaluate the results of the school effects obtained from the variance components of the error terms of the models. The variance components of each of these models and the school effect (intraclass correlation) can be found in Table 2.5. Figure 2.1 shows the intraclass correlation ρ for the specification with and without peer effects, and the null model. For the null model, the school effect is high for all Latin America countries - ρ is around 0.4. This result suggests that, on average, 40% of the student performance in such countries is explained by differences among schools. Chile presents the highest values for Mathematics and Science while Peru has the highest value for Reading. The lowest values, around 0.3, are found in Colombia (Reading), Costa Rica (Science), and Mexico (Mathematics).

Hanchane and Mostafa (2012) found that the school effect is around 7% for Finland and UK and around 20% for Germany. Although the results cannot be directly compared, Brunner *et al.* (2018) found that, overall, Finland, Iceland, Norway, Sweden and Denmark have a school effect of less than 15%, while Latin America countries have values above 30%.

When the explanatory variables are included, *i.e.*, taking into account student characteristics, family background and the school facilities - in the model without peer effect - there is an average reduction of 45% in the size of the school effect. The largest reduction is observed for Uruguay, with a fall of around 60% of the effect in the three areas of knowledge. The lowest reduction pointed out by the models without peer effects is around 30% for Mexico and Peru in Mathematics, and Costa Rica in Science.



Note: The *Null* model includes only the intercept, while *w/o p.e.* and *w/ p.e.* stand for without and with peer effect, respectively.

Figure 2.1 - Intraclass Correlation (ρ)

Lastly, when the peer effect is included, an additional reduction of the school effect of 1/3, on average, is observed. Chile presented the largest reduction for all three areas (around 50%), and Peru and Colombia presented similar results for Mathematics and Reading, respectively.

It is worth to mention that, even taking into consideration student factors (individual, family background and school facility) and also peer effects, the school effect is not negligible for Latin American countries (from 8% up to 22%). For Brazil, Costa Rica, Mexico, and Peru, the effect is above 20% for some areas, while Uruguay presented the lowest values (around 10%).

So far, these results point out to the existence of a certain degree of stratification among schools in Latin America, *i.e.*, there is a significant difference among schools. This difference is quite relevant in determining the student performance.

2.3.2 Student performance

Considering the three domains of PISA assessment, it can be observed that family background (ESCS) is statistically significant for all countries and positively related to the students' performance. In brief, the higher the socio-economic level and family culture, the

better the student performance should be. This impact, on average, seems to be smaller for Peruvian students (only in Mathematics) and higher for Uruguayan students.

Regarding students' individual characteristics, the results for gender gap point out that girls outperform boys in Reading, while boys perform better than girls in Science and Mathematics, for all the seven countries. Overall, the largest gender differences are found for the Mathematics' area. The largest differences for Reading are found in Uruguay and in Brazil, for Mathematics it is in Chile, Colombia and Costa Rica, and for Science it is in Colombia and Costa Rica.

Grade retention (REPEAT) is negative and statistically significant for all model in all countries. This finding suggests that if the student repeats a grade at least once, he/she tends to have worse performance than the others do. The effects on student performance is quite similar in all subjects, and is larger in Uruguay.

Other students' characteristics were included in some model specifications. For example, the enthusiasm for the subject under assessment (2009 and 2015) and the student level of dedication/perseverance (2012) were found positive and statistically significant for all countries. However, these results are not present here due to the high loss of observation in the sample. For 2012, for example, the models with the largest number of explanatory variables had the participation of less than 30% of the sample.

Concerning school facilities factors, it is worthy to highlight the variables perception of the student about disciplinary climate in the classroom (DISCLIMA and DISCLICI), and educational resource availability (SCMATEDU and SCIERES). The former is found to be positive and statistically significant for all countries but for Chile in mathematics, *i.e.*, the better the disciplinary environment in the classroom the higher the student performance on PISA assessment. This indicator intends to measure the students and teacher behaviour and interaction in the classroom. If there is too much "noise" due to student misbehaviour and the teacher fails to control it, the learning processes are negatively impacted and the student is expected to perform worse.

The variable educational resource availability (SCMATEDU and SCIERES) is also positive and significant for almost all countries. This result suggests that increasing educational resource availability may improve the student performance. When the model accounts for peer effects, educational resource availability is not significant for Uruguay (Reading and Science), Chile (Reading and Mathematics) and Colombia (Mathematics and Science).

The teacher's education degree is also included in the models. For the PISA editions of 2009 and 2012, the variable used is the percentage of teachers with higher education

(PROPQUAL). This variable is the proportion of teachers in the school who have an ISCED (International Standard Classification of Education) 5A qualification, *i.e.*, teachers with Bachelor, Master or equivalent degree. This variable is not significant for any country, which suggests that the higher education of a teacher is irrelevant in determining the student's performance. PISA 2015 models contemplate the percentage of teachers with Master degree or equivalent (PROAT5AM). In this case, this variable is positive and significant for Brazil, Mexico and Uruguay, *i.e.*, the larger the percentage of teachers with Master degree or equivalent the higher the student performance in Science for these countries.

Three other indicators included in this study that are related to the administration of the school resources are: the index of the deficit of teaching staff (for 2009/2012 editions was the teachers deficit index, TCSHORT, and for 2015 edition was the teachers and assistant deficit index, STAFFSHORT); the students-to-teacher ratio (STRATIO); and the school autonomy index for resource allocation (RESPRES). The first one appears to be not relevant to explain the performance of the students, except for Brazilian pupils in the area of science, where they observed a negative effect on the results. For the indicator of students-to-teacher ratio, some models presented significant but contradictory coefficients. The most intuitive hypothesis would be that more students per teacher could have a negative effect on student outcomes, as observed in the adjusted models for Brazil, in the three areas of knowledge, and for Colombia, only in mathematics. As for Mexico, Peru, and Uruguay in the area of reading, and for Chile in science, the effect was positive, that is, an increase in the number of students per teacher would have a positive effect on the students' results. The school autonomy index for resource allocation have, on the one hand, systematically significant effects for Brazilian students outcomes, in the three areas, meaning that the greater the autonomy of Brazilian schools, the better the results of their students. On the other hand, for Mexico, in the areas of mathematics and science, and for Colombia, in reading, the effect of autonomy was negative.

The results suggest that the school administration in Brazil has a significant impact on the student performance. This impact is twofold: the lack of staff in the school and the rigidity and difficulty in managing the available school resources diminish the performance of Brazilian students. It is worthy to notice that this finding seems to be important only for Brazil.

2.4 Final remarks

In order to assess the determinants of the Latin American students' performance, the multilevel approach is used on the last three PISA editions (2009, 2012 and 2015) data. The proposed procedure allowed us to point out, in general, that

1. the students' individual characteristics and family background;
2. the disciplinary climate in the classroom and educational resources availability;
3. the socio-economic status of the school and the performance of those surrounding the student (the peer effect), and
4. the differences among the schools (the school effect)

are the main determinants of the Latin American students performance on PISA.

The importance of the last two points is worthy of recognition: the cultural and socio-economic status of the school community and the difference among the schools per se are of paramount importance in determining the student performance. This result suggests that the better the environment surrounding the student the better his performance in PISA. This seems to make sense since inequality is very high in these countries.

It is worth to highlight a specific result for Brazil: the school administration is significant in influencing the student performance. This finding can be explained by the difficulties that the school manager has in allocating efficiently the available resources, which includes both teachers and staff personnel, and educational materials. These difficulties are found in public schools mostly, since government-managed schools have almost no administrative autonomy in Brazil.

Lastly, an implication of our results suggests that if Latin American countries governments intend to improve their students' performance, they should direct their policies to the schools and communities in disadvantages. Thus, they should give preference for policies that improve the school and the environment surrounding it, consequently, reducing the inequality in the country.

Table 2.2 - Estimation results - PISA 2009 (Reading)

Variables	Brazil		Chile		Colombia		Costa Rica		Mexico		Peru		Uruguay	
	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.
ESCS	6.854***	5.459***	10.28***	8.092***	11.23***	9.342***	9.686***	8.553***	7.897***	6.650***	11.91***	9.969***	15.12***	13.69***
	(0.602)	(0.615)	(1.264)	(1.309)	(0.815)	(0.833)	(0.923)	(0.941)	(0.362)	(0.369)	(0.984)	(1.006)	(1.123)	(1.144)
AGE	9.701***	8.679***	10.77***	9.997***	11.33***	11.17***	16.51***	16.15***	0.649	-1.641	7.266**	6.879**	13.44***	12.82***
	(2.143)	(2.140)	(3.772)	(3.764)	(2.901)	(2.889)	(3.577)	(3.569)	(1.449)	(1.455)	(3.080)	(3.073)	(3.952)	(3.946)
Female	22.78***	22.68***	15.74***	15.20***	7.665***	7.131***	9.858***	9.748***	14.79***	14.67***	7.858***	7.830***	29.74***	29.44***
	(1.212)	(1.210)	(2.332)	(2.310)	(1.689)	(1.677)	(1.962)	(1.960)	(0.740)	(0.739)	(1.925)	(1.912)	(2.221)	(2.217)
REPEAT	-43.22***	-40.70***	-46.97***	-43.66***	-42.81***	-41.89***	-47.51***	-46.07***	-42.27***	-37.33***	-39.09***	-37.71***	-63.16***	-57.60***
	(1.339)	(1.363)	(2.778)	(2.821)	(1.782)	(1.792)	(2.228)	(2.251)	(1.389)	(1.446)	(2.177)	(2.192)	(3.083)	(3.322)
DISCLIMA	4.834***	5.025***	2.256*	2.454**	9.289***	9.207***	3.511***	3.328***	4.321***	4.422***	12.47***	12.51***	2.379**	2.423**
	(0.728)	(0.725)	(1.261)	(1.250)	(1.049)	(1.042)	(1.149)	(1.145)	(0.455)	(0.454)	(1.188)	(1.184)	(1.143)	(1.138)
PROPQUAL	1.835	-9.956	52.76*	17.04	-0.0148	-7.491	8.464	5.519	6.838	6.552	45.76***	10.84	32.00	-5.519
	(8.420)	(7.147)	(28.51)	(21.06)	(9.840)	(7.258)	(8.698)	(7.257)	(5.674)	(4.559)	(10.58)	(8.483)	(36.97)	(31.82)
TCSHORT	-3.493*	-0.161	1.504	2.801	-3.489	-2.455	-4.325	-2.868	2.252	0.0875	-4.034	-3.028	-1.097	0.140
	(1.875)	(1.629)	(3.363)	(2.404)	(2.551)	(1.864)	(3.363)	(2.822)	(1.438)	(1.164)	(3.346)	(2.538)	(3.007)	(2.587)
STRATIO	-0.224*	-0.179*	0.263	0.239	-0.207	0.0404	0.683	0.519	0.247***	0.0832*	0.702**	0.434*	0.442	0.664*
	(0.118)	(0.0997)	(0.401)	(0.296)	(0.271)	(0.200)	(0.425)	(0.362)	(0.0545)	(0.0442)	(0.344)	(0.262)	(0.413)	(0.354)
SCMATEDU	10.91***	7.271***	8.688***	2.331	11.21***	3.798**	10.01***	4.305*	15.36***	3.652***	17.35***	7.481***	2.861	1.361
	(1.973)	(1.675)	(3.139)	(2.316)	(2.453)	(1.867)	(2.547)	(2.232)	(1.332)	(1.182)	(2.807)	(2.272)	(2.770)	(2.379)
RESPRES	23.97***	5.453**	9.416***	1.940	11.73***	-5.415**	8.384*	-5.122	10.07***	-2.197	9.418***	-2.858	27.22***	1.333
	(2.881)	(2.730)	(3.117)	(2.295)	(2.778)	(2.367)	(4.482)	(4.376)	(1.772)	(1.527)	(2.762)	(2.311)	(4.748)	(5.379)
MESCS		27.34***		23.38***		40.07***		23.77***		27.89***		40.33***		31.15***
		(2.643)		(3.883)		(3.236)		(4.428)		(1.552)		(4.265)		(5.471)
MREPEAT		-50.05***		-79.03***		-15.69		-36.45***		-48.27***		-30.72**		-11.81
		(6.291)		(12.73)		(12.18)		(13.60)		(4.574)		(14.89)		(8.778)
_cons	291.7***	357.9***	228.0***	307.6***	285.2***	320.3***	203.0***	233.6***	427.4***	495.8***	264.6***	338.7***	232.0***	255.5***
	(34.98)	(34.91)	(65.82)	(63.04)	(47.24)	(46.69)	(57.15)	(56.94)	(23.43)	(23.42)	(49.36)	(49.34)	(63.09)	(62.98)
N	11741	11741	3293	3293	6730	6730	3453	3453	25751	25751	5269	5269	4222	4222
AIC	131811.9	131606.2	36532.9	36442.9	75610.5	75451.5	37913.8	37853.1	284286.2	283840.5	59170.5	59045.3	48033.6	47972.1
BIC	131907.7	131716.8	36612.2	36534.4	75699.1	75553.7	37993.7	37945.3	284392.2	283962.8	59255.9	59143.8	48116.1	48067.3
LR	209.8		94.0		163.0		64.6		449.8		129.2		65.6	

Notes: Standard errors between brackets. w/o p.e. and w/ p.e. stand for without and with peer effect, respectively. *p<0.1, ** p<0.05, ***p<0.01.
N - Number of observations, *AIC* - Akaike Information Criterion, *BIC* - Bayesian Information Criterion, and *LR* - Log-likelihood Ratio χ^2 statistic.

Table 2.3 - Estimation results - PISA 2012 (Mathematics)

Variables	Brazil		Chile		Colombia		Costa Rica		Mexico		Peru		Uruguay	
	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w / p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w / p.e.	w/o p.e.	w/ p.e.
ESCS	7.440***	6.077***	12.13***	8.421***	11.50***	9.084***	9.039***	7.831***	6.416***	4.473***	6.530***	4.119***	12.85***	10.70***
	(0.595)	(0.610)	(1.199)	(1.263)	(0.888)	(0.923)	(1.144)	(1.175)	(0.467)	(0.487)	(1.383)	(1.423)	(1.230)	(1.263)
AGE	11.64***	11.05***	11.25***	10.84***	18.94***	19.03***	22.24***	21.79***	-0.977	-4.015**	12.67***	12.60***	8.715**	8.340**
	(2.034)	(2.030)	(3.279)	(3.269)	(2.847)	(2.835)	(4.056)	(4.046)	(1.832)	(1.851)	(4.491)	(4.478)	(3.805)	(3.790)
Female	-23.15***	-23.43***	-31.36***	-31.06***	-29.12***	-29.83***	-30.91***	-31.30***	-20.58***	-20.90***	-25.88***	-26.43***	-21.63***	-22.16***
	(1.157)	(1.155)	(2.006)	(1.978)	(1.723)	(1.710)	(2.286)	(2.282)	(0.923)	(0.922)	(2.732)	(2.714)	(2.229)	(2.220)
REPEAT	-41.45***	-38.89***	-49.18***	-46.09***	-35.41***	-33.98***	-36.88***	-34.91***	-41.98***	-35.32***	-39.56***	-38.25***	-64.45***	-58.17***
	(1.303)	(1.332)	(2.514)	(2.555)	(1.740)	(1.756)	(2.706)	(2.742)	(1.772)	(1.895)	(3.097)	(3.115)	(3.156)	(3.444)
DISCLIMA	5.977***	6.042***	0.372	0.318	7.497***	7.579***	4.981***	5.131***	7.685***	7.808***	6.253***	6.563***	7.057***	7.225***
	(0.651)	(0.649)	(1.105)	(1.090)	(1.013)	(1.006)	(1.384)	(1.378)	(0.531)	(0.528)	(1.673)	(1.666)	(1.191)	(1.183)
PROPQUAL	10.62	9.166	46.66***	9.666	10.49	7.044	-0.0659	-13.98	0.345	0.476	-9.205	-10.14	5.545	8.220
	(6.916)	(6.013)	(17.21)	(12.50)	(9.827)	(8.097)	(12.73)	(11.47)	(4.878)	(4.283)	(11.81)	(9.111)	(25.50)	(21.91)
TCSHORT	-0.933	0.387	-3.055	-2.556	1.098	-0.0198	2.361	0.173	-0.717	-0.209	2.655	2.561	-0.829	2.959
	(1.544)	(1.348)	(2.493)	(1.757)	(1.676)	(1.382)	(3.438)	(3.023)	(1.220)	(1.072)	(4.357)	(3.348)	(2.584)	(2.212)
STRATIO	-0.342***	-0.293***	-0.766**	0.0329	-0.638***	-0.488***	0.272	0.330	0.184***	0.0309	-0.00180	-0.276	-0.0431	0.0439
	(0.0985)	(0.0860)	(0.363)	(0.286)	(0.208)	(0.174)	(0.326)	(0.290)	(0.0580)	(0.0517)	(0.453)	(0.350)	(0.361)	(0.305)
SCMATEDU	8.138***	4.502***	8.847***	-0.513	6.728***	1.620	11.31***	5.642**	9.704***	3.906***	12.47***	5.400*	5.003*	4.229*
	(1.663)	(1.471)	(3.191)	(2.346)	(2.050)	(1.736)	(2.674)	(2.501)	(1.161)	(1.079)	(3.786)	(3.007)	(2.592)	(2.217)
RESPRES	20.54***	7.717***	15.90***	2.206	8.651***	1.331	8.114**	-1.484	4.160***	-4.126***	13.59***	2.582	18.28***	-3.638
	(1.924)	(1.944)	(2.417)	(1.917)	(2.164)	(1.933)	(3.545)	(3.574)	(1.433)	(1.357)	(3.206)	(2.743)	(3.893)	(4.069)
MESCS		22.92***		32.22***		28.29***		17.98***		20.70***		42.32***		33.68***
		(2.505)		(3.142)		(2.986)		(4.977)		(1.556)		(5.300)		(4.816)
MREPEAT		-42.39***		-54.47***		-33.59***		-47.59***		-39.94***		6.843		-9.626
		(5.702)		(11.29)		(10.10)		(14.43)		(5.090)		(22.02)		(8.054)
_cons	253.0***	298.4***	255.8***	308.1***	145.8***	179.2***	104.4	143.7**	459.8***	529.9***	217.1***	267.3***	329.7***	352.8***
	(32.88)	(32.82)	(54.47)	(53.12)	(46.43)	(46.01)	(65.19)	(65.08)	(29.16)	(29.50)	(72.48)	(71.89)	(60.48)	(60.18)
N	9141	9141	4007	4007	4698	4698	1849	1849	16626	16626	2109	2109	3232	3232
AIC	99728.8	99550.0	44198.1	44053.7	51268.9	51147.3	19674.2	19630.0	183836.2	183560.6	23258.5	23182.4	35973.2	35897.9
BIC	99821.4	99656.8	44280.0	44148.2	51352.9	51244.2	19746.0	19712.8	183936.5	183676.4	23332.0	23267.2	36052.3	35989.1
LR	182.8		148.4		125.6		48.2		279.6		80.0		79.4	

Notes: Standard errors between brackets. w/o p.e. and w/ p.e. stand for without and with peer effect, respectively. *p<0.1, ** p<0.05, ***p<0.01.
N - Number of observations, AIC - Akaike Information Criterion, BIC - Bayesian Information Criterion, and LR - Log-likelihood Ratio χ^2 statistic.

Table 2.4 - Estimation results - PISA 2015 (Science)

Variables	Brazil		Chile		Colombia		Costa Rica		Mexico		Peru		Uruguay	
	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.	w/o p.e.	w/ p.e.
ESCS	9.778***	8.059***	12.28***	9.144***	9.822***	7.832***	10.30***	8.252***	8.404***	6.900***	12.47***	9.881***	11.98***	10.15***
	(0.711)	(0.733)	(1.100)	(1.150)	(0.814)	(0.841)	(0.827)	‘(0.856)	‘(0.783)	‘(0.808)	‘(0.871)	‘(0.912)	‘(1.078)	‘(1.112)
AGE	11.29***	10.55***	18.61***	18.13***	16.15***	16.54***	7.561***	7.007**	11.42***	10.19***	14.59***	14.39***	9.768***	9.570***
	(2.417)	(2.412)	(3.008)	(2.996)	(2.398)	(2.393)	(2.793)	‘(2.785)	‘(3.028)	‘(3.038)	‘(2.609)	‘(2.600)	‘(3.382)	‘(3.374)
Female	-13.93***	-14.08***	-19.31***	-19.51***	-23.23***	-23.64***	-22.67***	-23.05***	-12.22***	-12.57***	-17.64***	-18.03***	-15.63***	-15.86***
	(1.373)	(1.370)	(1.821)	(1.803)	(1.407)	(1.402)	(1.562)	‘(1.557)	‘(1.526)	‘(1.524)	‘(1.620)	‘(1.608)	‘(1.968)	‘(1.961)
REPEAT	-45.38***	-41.97***	-51.49***	-48.59***	-42.63***	-41.74***	-38.89***	-37.50***	-33.66***	-29.01***	-40.52***	-38.70***	-60.97***	-55.40***
	(1.620)	(1.667)	(2.380)	(2.408)	(1.449)	(1.460)	(1.899)	‘(1.924)	‘(2.893)	‘(3.104)	‘(1.916)	‘(1.938)	‘(2.784)	‘(3.095)
DISCLISCI	5.560***	5.627***	5.742***	5.945***	5.726***	5.929***	3.758***	3.881***	7.883***	8.027***	4.353***	4.602***	3.815***	3.584***
	(0.727)	(0.723)	(1.059)	(1.049)	(0.785)	(0.783)	(0.858)	‘(0.853)	‘(0.899)	‘(0.896)	‘(0.910)	‘(0.905)	‘(1.032)	‘(1.028)
PROAT5AM	83.19***	56.36***	52.08*	6,004	42.47***	11.09	8,571	-3,043	33.71***	34.03***	8,516	1,918	244.2***	128.5**
	(18.53)	(15.71)	(26.97)	(19.00)	(15.93)	(13.29)	(11.14)	‘(8.555)	‘(10.71)	‘(9.307)	‘(13.55)	‘(10.58)	‘(63.69)	‘(58.39)
STAFFSHORT	-3.904**	-3.436**	-2,307	-1,652	-0.0584	0.470	1,611	0.917	-1,166	0.592	-2,353	-0.225	-2,225	-0.808
	(1.543)	(1.337)	(3.164)	(2.213)	(1.661)	(1.371)	(1.498)	‘(1.147)	‘(2.231)	‘(1.929)	‘(1.982)	‘(1.563)	‘(1.709)	‘(1.534)
STRATIO	-0.236***	-0.147*	0.0194	0.637**	-0.376***	-0.0830	-0.0772	-0.0510	0.138	0.0308	0.234	0.0972	0.154	0.0974
	(0.0888)	(0.0760)	(0.398)	(0.296)	(0.131)	(0.111)	(0.197)	‘(0.150)	‘(0.141)	‘(0.122)	‘(0.196)	‘(0.155)	‘(0.179)	‘(0.159)
SCIERES	4.837***	2.522***	5.429***	1.911**	3.346***	0.703	0.275	-0.138	4.856***	1.663**	4.205***	0.527	1.916*	0.746
	(0.751)	(0.659)	(1.174)	(0.849)	(0.961)	(0.821)	(1.143)	‘(0.878)	‘(0.840)	‘(0.788)	‘(1.000)	‘(0.823)	‘(1.024)	‘(0.928)
RESPRES	14.00***	4.319**	10.62***	-0.400	9.514***	1,131	-1,586	0.896	3,082	-4.050*	6.781***	-0.956	17.40***	2,988
	(2.007)	(1.884)	(2.362)	(1.802)	(1.693)	(1.585)	(2.937)	‘(2.274)	‘(2.345)	‘(2.166)	‘(1.578)	‘(1.409)	‘(3.097)	‘(3.341)
MESCS		23.48***		28.23***		30.04***		25.94***		22.77***		26.33***		25.60***
		(2.569)		(3.237)		(3.005)		‘(2.847)		‘(2.852)		‘(2.800)		‘(4.233)
MREPEAT		-44.30***		-67.99***		-23.88**		-20.22**		-28.37***		-30.41***		-11.32*
		(6.140)		(12.50)		(9.560)		‘(9.132)		‘(7.819)		‘(10.23)		‘(6.827)
_cons	258.4***	308.4***	155.0***	198.5***	202.0***	233.9***	330.7***	369.6***	233.0***	293.3***	181.0***	233.6***	320.1***	345.5***
	(38.58)	(38.62)	(48.52)	(48.15)	(38.44)	(38.43)	(44.45)	‘(44.38)	‘(47.70)	‘(48.16)	‘(41.69)	‘(41.58)	‘(53.90)	‘(53.76)
N	9896	9896	5474	5474	8492	8492	5437	5437	6147	6147	5982	5982	4829	4829
AIC	111827.6	111665.9	61081.4	60935.6	94336.4	94215.1	59543.4	59423.8	67835.6	67752.3	65910.5	65776.8	54365.8	54303.5
BIC	111921.2	111773.9	61167.3	61034.8	94428.0	94320.8	59629.2	59522.8	67923.0	67853.1	65997.5	65877.2	54450.1	54400.8
LR	165.6		149.8		125.2		123.6		87.4		137.6		66.2	

Notes: Standard errors between brackets. w/o p.e. and w/ p.e. stand for without and with peer effect, respectively. *p<0.1, ** p<0.05, ***p<0.01.
N - Number of observations, AIC - Akaike Information Criterion, BIC - Bayesian Information Criterion, and LR - Log-likelihood Ratio χ^2 statistic.

Table 2.5 - Variance decomposition and intraclass correlation

Country	Effect	2009 - Reading			2012 - Mathematics			2015 - Science		
		Null	w/o p.e.	w/ p.e.	Null	w/o p.e.	w/ p.e.	Null	w/o p.e.	w/ p.e.
Brazil	Between-School	2981.0	1328.8	876.6	2591.5	1105.4	777.4	2768.3	897.8	584.1
	Within-School	4527.8	3999.8	3991.8	3307.7	2835.6	2835.6	4827.1	4394.0	4394.0
	Overall	7508.8	5328.6	4868.4	5899.2	3941.0	3613.0	7595.4	5291.9	4978.1
	ρ	0.40	0.25	0.18	0.44	0.28	0.22	0.36	0.17	0.12
Chile	Between-School	3229.2	1192.7	518.0	4230.2	1236.5	515.9	3797.1	1231.5	511.8
	Within-School	3983.8	3590.3	3583.2	3789.5	3281.3	3281.3	4272.7	3812.3	3812.3
	Overall	7213.1	4783.1	4101.2	8019.7	4517.8	3797.3	8069.8	5043.9	4324.2
	ρ	0.45	0.25	0.13	0.53	0.27	0.14	0.47	0.24	0.12
Colombia	Between-School	2746.3	1173.8	556.7	2038.6	917.8	557.8	1790.1	780.6	482.0
	Within-School	4665.7	4113.4	4113.4	3449.6	2898.6	2892.9	4221.7	3670.2	3670.2
	Overall	7412.0	5287.2	4670.1	5488.1	3816.5	3450.7	6011.8	4450.7	4152.2
	ρ	0.37	0.22	0.12	0.37	0.24	0.16	0.30	0.18	0.12
Costa Rica	Between-School	2316.9	919.7	595.9	1966.5	862.6	618.9	1394.1	749.9	386.8
	Within-School	3751.8	3184.3	3178.0	2724.4	2182.0	2177.6	3547.5	3115.0	3108.8
	Overall	6068.8	4104.0	3773.8	4690.9	3044.6	2796.6	4941.6	3865.0	3495.7
	ρ	0.38	0.22	0.16	0.42	0.28	0.22	0.28	0.19	0.11
Mexico	Between-School	3077.9	1396.9	845.6	1919.8	1045.2	748.4	1590.8	709.1	477.2
	Within-School	3526.3	3320.9	3320.9	3568.9	3334.2	3334.2	3568.9	3408.4	3401.6
	Overall	6604.2	4717.8	4166.5	5488.7	4379.5	4082.7	5159.7	4117.5	3878.8
	ρ	0.47	0.30	0.20	0.35	0.24	0.18	0.31	0.17	0.12
Peru	Between-School	4610.1	1489.2	765.1	3287.9	1636.0	864.4	1994.2	794.7	420.7
	Within-School	4527.8	4048.1	4048.1	3633.7	3197.1	3197.1	3707.1	3307.7	3307.7
	Overall	9137.9	5537.3	4813.2	6921.6	4833.1	4061.5	5701.3	4102.4	3728.4
	ρ	0.50	0.27	0.16	0.48	0.34	0.21	0.35	0.19	0.11
Uruguay	Between-School	3744.3	854.1	566.8	3102.6	777.4	484.9	2555.5	528.5	372.4
	Within-School	5653.3	4827.1	4817.4	4411.6	3707.1	3692.3	4827.1	4307.0	4298.4
	Overall	9397.7	5681.2	5384.2	7514.2	4484.5	4177.2	7382.6	4835.5	4670.8
	ρ	0.40	0.15	0.11	0.41	0.17	0.12	0.35	0.11	0.08

Notes: w/o p.e. and w/ p.e. stand for without and with peer effect, respectively. ρ is the intraclass correlation

3. EFFECT OF PUBLIC SPENDING ON THE QUALITY OF EDUCATION: AN ANALYSIS BASED ON BRASILIAN MUNICIPAL SCHOOLS IN THE PERIOD BETWEEN 2009 AND 2017

3.1 Introduction

The economic literature reports robust evidence that education has positive effects on economic growth[6]. As the quality of education is one of the pillars for sustainable economic development and therefore a recurrent demand of society, governments should properly direct efforts and resources to this area.

The way a government should intervene and invest in education is still a subject of much discussion. While some authors argue that there is no significant or relevant evidence that increasing the investment in education results in a systematic improvement of student outcomes (Coleman, 1966; Hanushek, 1986), others demonstrate that this improvement exists (Word, 1990; Nye, 1992; Baker, 2016) and can be a powerful tool for reducing social inequality and stimulating the local economy (Johnson, 2011).

In recent years, Brazil has considerably expanded resources for education. As can be seen in Figure 3.1, the estimate of direct public investment in education jumped from 3.9% of GDP in 2000 to about 5.1% in 2015. According to OECD data for the year 2015, in addition to direct and indirect expenditures with education from elementary to higher education, investments in Brazil reached 5.5% of GDP, a percentage higher than the OECD average of 4.5% (OECD, 2018). Another indicator of educational funding that had a significant increase, also presented in Figure 3.1, was direct public investment in education per student. In real terms and considering the period between 2000 and 2015, the indicator almost tripled its value, from R$ 2,587.00 to R$ 7,273.00[7].

Parallel to the expansion of spending on education, the Brazilian educational system has made important advances in school access statistics and flow indicators. By 2015, about 98% of the population between the age of 6 and 14 had access to school. For the population aged 15 to 17 years, access rose from 62.5% in 1995 to 84.3% in 2015[8]. Regarding flow indicators, the approval rate has increased at all levels and the age-grade distortion (percentage of students

[6] Mankiw *et al.* (1992) and Mincer (1974) explore the effect of schooling measures on economic growth. Hanushek *et al.* (2008) and Hanushek and Woessmann (2012) show that the cognitive abilities of the population are related to individual gains, income distribution and economic growth.
[7] Further details on educational financing indicators can be found at the link: http://inep.gov.br/web/guest/indicadores-financeiros-educacionais.
[8] Data from the website Todos pela Educação (http://www.todospelaeducacao.org.br/).

with school delay) plummeted. Between 2006 and 2017, the age-grade distortion fell from 28.6% to 18.1% in primary education, and from 44.9% to 28.2% in secondary education[9]. Despite these advances in access to the educational system, the quality of education offered has been constantly questioned.

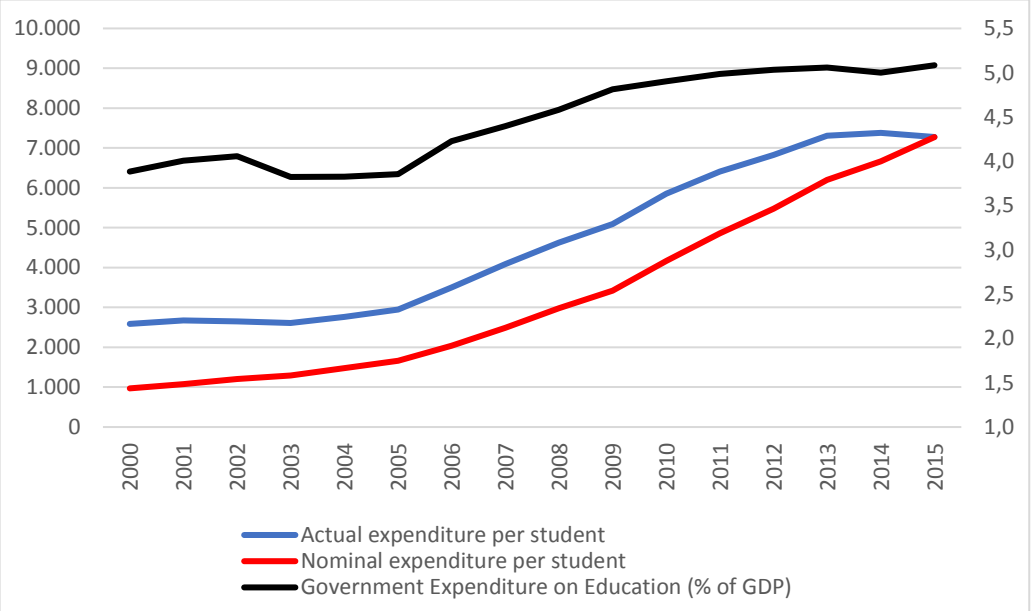


Figure 3.1 - Estimate of the Direct Public Investment in Education per Student (real and nominal values) and Estimate of the Percentage of these investments related to the Gross Domestic Product (GDP)

Even with the increase in investments, the results achieved by Brazilian students in large-scale periodic educational evaluations (national such as SAEB[10] and international such as PISA[11]) have not been satisfactory. Over the last three editions of Pisa (2009, 2012 and 2015), for example, the average results of Brazilian students were practically the same in Reading and Science assessments, and there was a slight drop in Mathematics, as can be seen in Figure 3.2. Moreover, these results are well below the average achieved by OECD member countries as well as by Latin countries such as Chile, Uruguay and Colombia.

Given this scenario, this study aims to evaluate the effect of public spending on the quality of the educational system. For this purpose, the data from the National Education Development Fund (FNDE) and from the Public Budgeting Information System (SIOPE) were

[9] Further details on the approval rate and the age-grade distortion index can be found at: http://portal.inep.gov.br/web/guest/indicadores-educacionais

[10] The National System of Evaluation of Basic Education (SAEB) is a large-scale assessment carried out in Brazil, applied to students enrolled at the end of each cycle of basic education. Currently the evaluation is performed every two years. See: http://portal.inep.gov.br/web/guest/educacao-basica/saeb.

[11] The Programme for International Student Assessment (PISA) is a triennial evaluation coordinated by the Organization for Economic Cooperation and Development (OECD). See: http://www.oecd.org/pisa/.

used, which depict current (maintenance) and capital (investment) expenditures[12] of municipalities for basic education (which includes both ISCED 1 and ISCED 2[13]). To portray the quality of the educational system, we chose to use the Basic Education Development Index (IDEB)[14] of municipal schools that attend primary education in the initial years, also called ISCED 1. This indicator was chosen since it combines students learning information (performance in large-scale assessments) and his/her flow (grade repetition rate), which are two important dimensions of educational quality. The multilevel model, also known as the mixed effects model and hierarchical model, was used in the empirical approach. In addition, the various adjusted specifications took control variables into account that represented characteristics of the educational institutions and the municipalities.

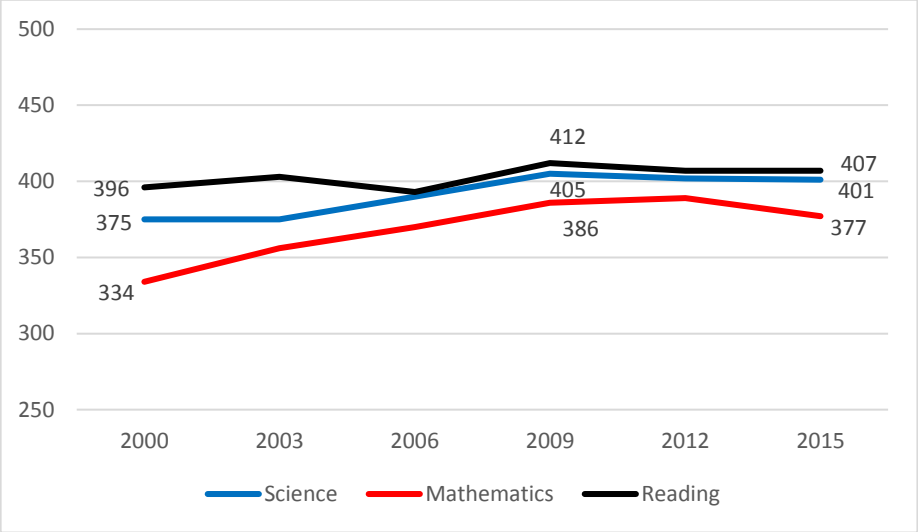


Figure 3.2 - Evolution of the Brazilian students' performance in the PISA

This paper intends to contribute to the discussion about the role of educational investments in improving the quality of education, bringing a distinction between the effects of the current expenditure and the capital expenditure on the quality of municipal education institutions. In addition, the SIOPE/FNDE education expenditure data are little used in their gross form in studies of this nature. Despite the greater difficulty in working with data of small granularity such as these, the detailed allocation of resources allows more precise analyses and

[12] Data on the expenses of the municipalities with education, see: https://www.fnde.gov.br/fnde_sistemas/siope/relatorios/arquivos-dados-analiticos

[13] According to the International Standard Classification of Education (ISCED) 2011, edited by the UNESCO Institute for Statistics (UIS), the ISCED 1 is the primary level of education and ISCED 2 is the lower secondary level of education. It corresponds, in Brazil, to the cycle that goes from the first to the fifth year of elementary school (from 6 to 10 years of age) and from the subsequent four years of education (from 11 to 14 years of age), respectively.

[14] For further details about the IDEB, see: http://inep.gov.br/web/guest/IDEB.

the effective reduction of bias caused by errors resulting from data classification and aggregation.

The article is organized as follows: Section 3.2 describes how the public financing of education in Brazil is. Section 3.3 provides a brief review of the literature on the effect of public spending on the quality of education. The methodological approach containing the data description and the empirical strategies used to measure the effect of public spending on the quality of education are presented in section 3.4. The adjusted models and the discussion of the research results can be checked in section 3.5. At last, section 3.6 brings the final considerations of the work.

3.2 Educational Financing in Brazil

The two main legal instruments dealing with the structure of Brazilian educational financing are the Federal Constitution of 1988[15] and the Law of Directives and Bases (LDB) of 1996 (Law 9,394/1996)[16]. The Federal Constitution, in its art. 212, determines that the Union must apply at least 18% of its income taxes on maintenance and development of education (MDE), while the states, the DF and the municipalities, 25%. In turn, LDB establishes which expenses can be considered as MDE and what is not considered MDE.

The LDB also determines the responsibility of each federative entity in relation to the provision of education services. According to the law, municipalities are responsible for providing early childhood education and, with priority, elementary education; the states should be responsible for ensuring elementary education, for offering priority to secondary education, and for defining, together with the municipalities, forms of collaboration in the provision of elementary education, ensuring proportional distribution of responsibilities. The Union, in addition to its higher education network and its presence in other levels and modes of education, must exercise a technical support and financing function and articulate all the organization of national education.

The Federal Constitution, in its art. 206, establishes that education should be provided with equal conditions for access and stay in school, and for ensuring quality standards. However, even the defined minimum percentage amount of 25% for states and municipalities is not sufficient to guarantee the equality of conditions, since the capacity of financing of

[15] The Federal Constitution of 1988 can be accessed through the link http://www.planalto.gov.br/ccivil_03/constituicao/constituicaocompilado.htm

[16] The LDB can be accessed through the link http://www.planalto.gov.br/ccivil_03/LEIS/L9394.htm

entities is quite different. Soares (1998) presents a discussion about the high inequality in the financing capacity of the educational policies of the municipalities and states.

Considering the Brazilian educational deficit and the inequalities observed in educational systems, in 1998 the government created the Fund for Maintenance and Development of Elementary Education and Acknowledge of Teaching - FUNDEF[17]. This fund contributed to a substantial reduction of inequalities between entities of the same state, since resources were redistributed according to the number of students enrolled in elementary education. Thus, a fixed amount of student/year was established in elementary education within the state (Ulyssea *et al.*, 2006). In 2006, in order to correct some distortions, the FUNDEF was replaced by the FUNDEB[18]. This new fund follows the same logic of redistribution as the previous one, but all the stages and modalities of basic education were incorporated, new sources of income were increased, the percentage of allocation to state funds increased, and a minimum percentage was set for complementing the Union, equivalent to at least 10% of the total value of the funds. This logic of redistribution of resources by enrolment and the existence of a complementation of the Union for the states with fewer resources, to guarantee a minimum per national student, have brought important advances in the system of financing of basic education.

There are also other educational funding programs managed by FNDE, such as: National School Feeding Program (PNAE); School Transportation Program (PNATE), School Direct Money Program (PDDE); National Textbook Program (PNLD), National School Library Program (PNBE), National School Health Program (PNSE). These programs, intended for public schools, aim to assist in the development of some educational activities.

Lastly, in 2014, the National Education Plan (PNE) 2014-2024[19] was sanctioned. This plan brings 20 goals built from the demands of social entities and the main interlocutors and researchers in the educational area. These targets must be met throughout the life of the plan. Target 20, one of the most important and controversial, proposes to increase public investment

[17] FUNDEF consists of a change in the financing structure of Elementary School by linking to this level of education a portion of the resources constitutionally allocated to Education. With Constitutional Amendment No. 14/96, 60% of these resources (which represents 15% of the total collection of states and municipalities) are reserved for elementary education. In addition, it introduces new criteria for the distribution and use of 15% of the main taxes of states and municipalities, promoting their sharing of resources between the state government and its municipalities, according to the number of students attended in each school network.

[18] The Fund for Maintenance and Development of Basic Education and Acknowledge of Education Professionals (FUNDEB) was created by Constitutional Amendment No. 53/2006 and regulated by Law 11,494 / 2007 and by Decree 6,253/2007, replacing the Maintenance Fund and Development of Elementary Education and Acknowledge of Teaching - FUNDEF, which was in force from 1998 to 2006.

[19] Further details on the National Education Plan can be found at http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2014/Lei/L13005.htm

in public education, reaching 7% of Gross Domestic Product (GDP) in 2019 and 10% in 2024. This shows that public entities will need to make a great effort to reach this goal, since the estimated public investment in education was about 5% of GDP in 2015 (Brazil, 2018).

3.3 Theoretical Framework: Relationship between expenditure and educational indicators

The relationship between spending and results in education has motivated several scholars over the last decades. Despite the growing sophistication of the analytical methodology used and the wide availability of public educational and financial data, there is still no consensus on the relationship between expenditure on education and educational indicators. The conclusions are divided between those who consider that there is a strong association between the financial volume spent with the educational system and those who do not identify this relationship as true.

Some of the authors who defend the lack of this relation attribute the variability of the students' average performance to intangible factors by the school investment, such as family history and characteristics of the environment in which the school is inserted. Among these articles, the so-called "Coleman Report" (Coleman, 1966), Hanushek's review of educational analysis (Hanushek, 1986), and subsequent articles in which Hanushek (Hanushek 1989, 1996a, 1996b, 1997, 1998) reiterated his position. Coleman and Hanushek were particularly important in support of public educational policies adopted by municipalities and US states in the years following their publication, supporting the subsequent containment of investment in education (Rothstein, 2002). Subsequently, other authors directly refuted the methodology of literary summarization (meta-analysis) with the use of counting of votes used by Hanushek. According to Krueger (2002) and Baker (2016), a skewed count of the number of estimators, rather than studies, would lead to probable misleading conclusions about the positive impact of investment in education.

Al-Samarrai (2006) conducted an international comparison evaluating the impact of spending on education on school performance, with a focus on developing countries, particularly those on the African continent. The results indicated that the education expenditures of these countries do not present a relation that is consistent with the educational performance. The author further emphasizes that just raising resources is not enough, and that institutions have an important role in converting resources into better school outcomes.

Other works present diverse opinions on the impact of public investments in education. Word (1990), using data from the STAR[20] project, evaluated the impact of the student/teacher ratio and concluded that smaller classes provided better student performance. The data obtained from this project were used in several studies and allowed to establish a scientifically proven parameter of the influence of the class size on student performance in the initial years. Nye (1992) followed the sample of STAR project students two years after the end of the project and found that students who had been assigned to smaller classes (15 students per teacher) performed significantly better than the other students. More recent studies, such as Hyman (2017) in the US and Gibbons *et al.* (2018) in the United Kingdom, have evaluated the effect that spending has on student performance. These studies showed that an increase in expenses per student had a positive impact of a relevant magnitude on the students' results. However, existing problems in school resource allocation programs, pointed out in these studies, tend to mask this effect, which adds to the list of precautions in the treatment of data for studies of this nature.

In Brazil, the evaluation of the effect of public spending on educational indicators has also been a well explored topic. As observed in the international literature, the results are antagonistic. From nine studies analysed, three indicate that an increase in education spending has a positive effect on the educational system (Menezes-Filho and Pazello, 2007; Sobreira and Campos, 2008; and Soares and Clemente, 2013). About the remaining studies, three did not find any effect (Anunciação and Verhine, 2006; Menezes-Filho and Amaral, 2009; Gouveia *et al.*, 2009; and Diaz, 2012), one found a very small effect (Kroth and Gonçalves, 2014), and one found that the effect was significant only for some of the tested indicators (Simielli and Zoghbi, 2017).

Menezes-Filho and Pazello (2007) use the date of implementation of FUNDEF as a differentiating factor of teachers' salaries and, based on a strategy of differences-in-differences, evaluate the evolution of students' scores in SAEB editions of 1997 and 1999. The results suggest that a possible increase in teachers' salaries caused by the implementation of this fund had a positive effect on the performance of 8th grade students. Using a panel of random effects and aggregate data per unit of the federation, Sobreira and Campos (2008) show that an increase in annual per capita spending with FUNDEF has a positive effect on the average performance of states in SAEB. Another study highlighting the importance of public spending on educational

[20] Random experiment conducted by the *Tennessee State Department of Education* where more than 7,000 students and their teachers were relocated in classes of varying sizes and studied between 1985 and 1989.

indicators was that of Soares and Clemente (2013). From a panel with random effects applied to the data from 399 municipalities of Paraná, these authors conclude that the expenses with the average remuneration of teachers is the main input that generates a positive effect on the IDEB of these municipalities.

Kroth and Gonçalves (2014) evaluate the effect of total education expenditures in conjunction with social expenditures (social assistance, health, and culture) of Brazilian municipalities on the results of *Prova Brasil*[21]. They concluded that there is a complementarity between spending on education and spending in the social area, and that total spending on education has a positive effect on performance. However, they considered this effect small. Simielli and Zoghbi (2017), using fixed effects panels and data from 2007 and 2011, explored the relationship between municipal expenditures with elementary education and five educational indicators: dropout rate, approval rate, grades at Mathematics and Reading on the *Prova Brasil* test, and the IDEB. The results indicated that the expenditure per student does not have a statistically significant effect on the educational indicators for the 5th year of elementary school and that there is a positive impact of low magnitude for the 9th year of elementary education.

Contrasting the results of the national studies that find some effect of the expenditures on the quality of education, Anunciação and Verhine (2006), based on data from Bahia municipalities, do not find a significant correlation between the financial variables of these municipalities and school performance. Menezes-Filho and Amaral (2009), using 2005 data of municipal expenditures per elementary student and the average scores of Portuguese and Mathematics semantics of *Prova Brasil*, find small positive effects and statistically insignificant for most of the adjusted specifications. The study by Gouveia *et al.* (2009) uses data from 32 municipalities in Paraná and concludes that there is no correlation between expenditures and the IDEB. Only for a cut of municipalities with worse results in the IDEB is a positive correlation between the evolution of spending (2001-2005) and the IDEB. Finally, Diaz (2012) uses a hierarchical two-tiered model (schools and municipalities) to evaluate the effect of financial variables on the IDEB of 2005 and concludes that an increase in the percentage of spending on education and an increase in the percentage of spending with basic education do not guarantee improvement in the quality of education.

[21] The Brazil Assessment (*Prova Brasil*) corresponds to one of the SAEB students' groups. Further details on this large-scale assessment can be found at: http://portal.inep.gov.br/educacao-basica/saeb/sobre-a-anresc.

Unlike the studies mentioned here, which generally use financial data from FINBRA (Finances of Brazil/National Treasury) or the state itself, this study considers the SIOPE/FNDE data. This database, although much more complex, provides a detailed account of the origin, destination and application of financial resources for education. It is possible to use non-aggregated data on the expenses of each municipality distinguished by the economic category of expenditure (cost and investment), the nature of the expenditure (personnel and social charges, consumer material, interest and debt charges, etc.), and even identify the element of expenditure. In addition, most of the mentioned studies were performed at the municipality or state level and used data for a maximum of three periods, with 2011 being the most recent year. In this study, biennial data were considered between 2009 and 2017, and public expenditure was disaggregated according to the nature of the expenditure. With this, it was possible to measure separately the effect of costing and capital expenditures on the quality of municipal schools that attend the ISCED 01 education.

3.4 Methodology: Data and Empirical Strategy

Since the study of Coleman (1966), the concept of production function from microeconomics theory has been widely used in educational studies to relate factors that affect the quality of educational systems. In fact, it can be considered that the provision of educational services, like any other service in the economics field, is the product resulting from the combination of several factors involved in its generation. The generation technology of educational services may depend on numerous factors and is subject to random shocks from economic conditions, political decisions and conflicts, among other aspects that may directly or indirectly affect the quality of education systems in a country, state or municipality.

In this way, one can understand a function of education production as a combination of factors that maximize the quality of the transmission of knowledge that is offered by educational institutions to its students. This function can be expressed through a model that outlines the relationship between the educational inputs and the output of the educational system on the student.

According to Fernandes (2007), an educational system that systematically retains its students, causing much of them to leave school ahead of time, is not desirable. Neither can be considered satisfactory a system that approves its students automatically, allowing them to complete the school cycle without having acquired the appropriate level of knowledge. Starting from this premise, a good teaching institution could be defined as one in which its students acquired the necessary knowledge at each stage of teaching and did not waste time with

repetition or early quitting studies. Thus, indicators of school flow (retention rate, average completion time of a given cycle/teaching stage), and learning (as measured by students' results in regular large-scale assessments) could be used as proxies for the quality of the institution's teaching.

In relation to the inputs, several factors linked to the school and the educational system can be explored, such as school infrastructure, training and motivation of education professionals, socio-economic conditions of the community, and available financial resources. For this study, the focus is on the evaluation of the effect of the financial resources that the municipalities invest in education. These resources were aggregated according to the expenditure nature group, in order to separately measure the effects of current and capital expending on education. The other inputs included in the data modelling are used only to control the effect of other characteristics that may affect the quality of the educational institution.

In the next subsection, the indicators of expenditures of municipalities with education, the IDEB (index chosen to portray the quality of the educational institution), and indicators used as controls in data modelling are detailed. The empirical strategies and specifications adopted are presented below.

3.4.1 Data

To conduct this study it was necessary to consider public databases with information about the municipalities and their educational institutions. Data related to the municipal education network were obtained from the National Institute of Studies and Research in Education Anísio Teixeira (INEP), which is responsible for planning and executing educational censuses, assessments and large-scale exams in the country. The expenditures data of municipalities with education were extracted from the Information System on Public Budgets in Education (SIOPE), which is administered by FNDE.

Expenditures of Municipalities with Education

SIOPE is an electronic system for collecting, processing, disseminating, and publicly accessing information on education budgets of the Union, the States, the Federal District, and the municipalities. Available databases provide detailed data on education revenues and expenditures that provide information on the application of resources in the maintenance and development of education (MDE), in the FUNDEB, and in the remuneration of teaching professionals.

For this study, the total gross expenses of Brazilian municipalities was used for the period between 2008 and 2017, with the last update occurred on 07/10/2018. On this basis, the information on committed, settled, and paid expenditures of Brazilian municipalities should be identified from three variables. Two of them are sub-function classification variables (CO_EXIBICAO_PASTA and CO_EXIBICAO_PASTA_PAI), related to the stages and modalities of education. The third variable (CO_CONTA_CONTABIL) identifies the expenditure through certain aspects (*e.g.* the economic category, the nature, and the element of this expenditure). It is important to note that the information available at SIOPE is self-declaratory and that its submission to FNDE is mandatory. However, it does often present missing data, mainly when information is not reported by some federative entities.

In this study, it was decided to consider the settled expenses[22] related to elementary education. The expenses in elementary education destined to the teaching of Youth and Adults (EJA) and to special education (EE) where excluded, since the indicator used to portray the quality of education refers to the regular modality of teaching, that is, it does not include students enrolled in the EJA and EE.

The education expenditures of the municipalities were treated from three different specifications. The first specification takes into account the breakdown according to the economic category of the expenditure, that is, the total expenses were separated into current expenses and capital expenditures[23]. The second specification used capital expenditure in the same way as in the previous specification. However, interest expenses and debt charges were deducted from current expenses, with only current expenses with personnel and social charges and other current expenses, which were treated as separate variables. The third specification is similar to the second, but only expenses classified as direct applications are considered. Thus, the indicators of this specification refer to: direct applications in personnel and social charges; direct investments in other current expenses; and the sum of direct investments in investments and financial investments. These last two specifications have the advantage of separately measuring the effects of current expenses with personnel and social charges, and other current expenses. Another advantage is the exclusion of some expenses that are not defined as expenditures in the MDE and that, therefore, end up taking out resources that could be allocated directly in the school.

[22] The settled expenses refer to those expenses committed in which the delivery of the material or service, in terms of art. 63 of Law No. 4,320/1964.

[23] Current expenses include current costs and transfers. Capital expenditures are those intended for the formation or acquisition of capital goods and are comprised of investments, financial investments and capital transfers.

All expenditure variables were converted to the 2017 values using the IPCA. Then, those values were divided by the number of students enrolled at the regular basic level in municipal schools, according to the year of expenditure. For example, the current expenditure for the year 2010 was divided by the number of students enrolled at the regular basic level in municipal schools, in 2010.

Lastly, capital expenditures were deferred over a period, assuming that their effect does not occur in the current year, but afterwards. It seems reasonable to assume that increases in education investments would have their effect measured more efficiently only in the long run. However, given the limitation of the data, only one lag was possible.

Education Quality

One could define a good teaching institution as that in which their students learn the necessary contents and are promoted at the end of each step. Starting from this concept, two dimensions can be highlighted to represent a quality teaching system: the flow of the student and the learning of the content offered. To portray these two dimensions in a single indicator, INEP created in 2007 the Basic Education Development Index (IDEB). The index is calculated by combining the average non-retention rate (school flow) with the average student performance in the Mathematics and Portuguese language assessments of the SAEB (learning).

The IDEB can be calculated by various aggregations, such as by geographical location (state, municipality, school, etc.), by type of network (public or private), by administrative dependency (state or municipal), and by educational stage (ISCED 1, ISCED 2, and ISCED 3). As the focus of this study is to evaluate the effectiveness of the financial resources destined to the institutions under the responsibility of the Brazilian municipalities, the IDEB was chosen from municipal schools that offered ISCED 1 schooling (1st to 5th year) from 2009 to 2017.

Control Variables

In addition to the expenditure indicators of municipalities with education and the IDEB of municipal schools, other information contained in INEP databases was considered. This information refers to characteristics of the school and the municipal education network and were used as control variables in the empirical strategies presented in the next subsection.

The control variables related to educational institutions depict the following aspects: basic infrastructure, pedagogical resources, complexity of the management, ratio between student and teacher numbers, average students per class, and percentage of teachers with higher education. These indicators were constructed based on information extracted from the School

Census micro-data from 2009 to 2017[24]. Only the indicators that represent the average number of students per class and the percentage of teachers with higher education were extracted directly from the INEP website[25]. In addition to these school-related controls, an index that represents the size of the municipal education network was also created, based on information from the school census.

The information from schools in the municipal school network were considered to construct the indicators that portray the basic infrastructure, pedagogical resources, complexity of school management, and the size of the teaching network of the municipality. The statistical technique of factorial analysis (Johnson and Wichern, 1992) was used to reduce the dimensionality of the data set. This technique is used in the construction of indexes and its purpose is to describe the original variability of the random vector in terms of a smaller number of variables called factors that are related to the original vector through a linear model. The generated factors are independent and represent a certain latent trait expressed by a larger set of variables, which allows to circumvent multicollinearity problems in linear models. The results of the factor analyses can be found in Figure A.1 of the Appendix.

The basic infrastructure indicator was constructed from nine variables with information about schools, namely: whether the school has access to public services for the supply of electricity, water, sewage treatment, and garbage collection; if the school has a room for the board, a teacher's room, and bathrooms inside the building; and whether the school has adequate routes, facilities, and restrooms for students with disabilities or reduced mobility. The first factor represents about 46% of the total variability of the data and the correlation measures between it and the original variables varied between 0.53 and 0.83.

For the construction of the index of pedagogical resources of the school were used five variables of the school table: existence of computer laboratory, science laboratory, sports court, library, and internet. The first factor represents more than 50% of the total variability and its correlation with the original variables, in general, was higher than 0.7, being lower only for the variable that measures the existence of a science laboratory, a rare resource for schools of the municipal education network.

The complexity index of the school management was constructed from information extracted from the tables of enrolments, classes, and teachers of the school census. This indicator assumes that the level of school management complexity is determined by its size, the

[24] School census microdata can be obtained from: http://portal.inep.gov.br/web/guest/microdados
[25] See: http://portal.inep.gov.br/web/guest/indicadores-educacionais.

number of stages and modalities offered, and the number of shifts. To portray the size of the school, the number of students enrolled and the number of teachers working at the institution were used as proxy. The information on the stages/modalities of teaching in the table of enrolments was reclassified in six levels: ISCED 0, ISCED 1, ISCED 2, ISCED 3 (including Teaching), technical ISCED 3, and adult education. After defining this classification, the number of stages/modalities offered was calculated for each school. Finally, in order to calculate the number of shifts in the schools, the information on the start time of their classes was considered and the classes were classified as morning (between 5:00 a.m. to 10:59 a.m.), afternoon (11:00 a.m. to 4:59 p.m.), or night time (5:00 p.m. to 4:59 a.m.). From this information, the schools were classified according to the number of shifts in which their classes work. Figure A.1 presents the synthesis of the factor analysis applied to this set of variables. Note that the first factor accounts for almost 65% of the total variability of the original data and that the correlation between it and the four indices used in this analysis ranged from 0.63 to 0.89.

To calculate the ratio between the number of students and the number of teachers, the enrolment and teacher tables of the school census were used. To obtain this ratio, the total number of students and teachers enrolled in the school was considered. It is important to highlight that the indicators used as controls of school characteristics were not restricted to the initial stages of elementary education, since their purpose is to portray the infrastructure conditions, pedagogical resources and the complexity of school management as a whole. Only the indicators that measure the percentage of teachers with a higher level and the average number of students per class refer to the initial stages of primary education.

Finally, to portray the size of the teaching network of the municipality, an index was created based on the total number of schools, students, and teachers of the municipal network. The factor created to depict this dimension represents more than 90% of the total variability of the original vector, as can be seen in Figure A.1. In addition, the correlations between this generated factor and the other variables that compose it were above 0.9.

3.4.2 Empirical Strategy

In order to evaluate the effect of the public expenditures of Brazilian municipalities on the quality of municipal schools, the multilevel model was used as an empirical strategy. This model, also known as a hierarchical model or mixed effects model, incorporates the hierarchical structure of the data and allows to treat the intercept and slope coefficients as random variables,

different from what occurs in traditional linear models, in which the intercept and the coefficients are fixed.

Rasbash *et al.* (2017) states that the use of OLS models in data with hierarchical structures is inadequate, since this methodology does not allow to quantify the variation between levels. By incorporating the hierarchical structure, multilevel analysis increases the accuracy of the estimators relative to the specific units, allowing the researcher to better understand the effects of this hierarchy and to elaborate more complex questions. In addition, when considering the partitioning of variance into components, this methodology avoids underestimation of the standard errors of the coefficients.

For this study, three different specifications were considered. In the first one, the model was structured in two hierarchical levels, time and school, and with random effects only in the intercept, as shown below:

$$\text{Level 1 – Time:} \quad y_{ti} = \beta_{0\text{i}} + \beta_1 D_t + \delta \text{G}_{ti} + \lambda X_{ti} + \varepsilon_{ti} \tag{3.1}$$

$$\text{Level 2 – School:} \quad \beta_{0i} = \text{c} + u_{0i} \tag{3.2}$$

Replacing (2) into (1):

$$y_{ti} = \text{c} + u_{0i} + \beta_1 D_t + \delta \text{G}_{ti} + \lambda X_{ti} + \varepsilon_{ti} \tag{3.3}$$

where y_{ti} is the value of the IDEB of elementary school years in year t for school i, X_{ti} represents the vector of control covariables with the characteristics in period t of school i, and G_{ti} is the vector of covariates referring to expenditures with education made in year t by the municipal school network i. For this study, the random vector G_{ti} can be composed of two (current and capital expending) or three covariates (current expenses with personnel charges, other current expenses, and capital expenditures), according to the adopted specification. D_t represents the fixed effect of time, which in this study was treated from temporal dummies because data are available for only five years[26]. ε_{ti} and u_{0i} are random components related to level 1 (Time) and level 2 (School), respectively. The main difference between the specification presented in (3.3) and the multiple regression is the presence of two random components.

Equation 3.3 corresponds to a multilevel model with a random intercept, that is, the intercept is divided into two elements: one fixed and one random. The fixed element c represents the global intercept, which is constant for all periods and schools and corresponds to

[26] The municipal expenditures database has annual information for the period 2008 to 2017. The IDEB has biennial information for the period between 2005 and 2017. Thus, they have five overlapping years.

the mean of the β_{0i} intercepts. The random term u_{0i} represents how much the i school is distant from the global intercept. The random component can be interpreted as the unique effect of the i school in relation to the global average and represents the stable characteristics of the school that are not observable. The assumptions for estimation of equation 3 are:

1. The random components, error terms of levels 1 and 2, are normally distributed and are independent of each other.

$$\begin{pmatrix}\varepsilon\\ u\end{pmatrix} \xrightarrow{i.i.d} \mathcal{N}\left(\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}\sigma_\varepsilon^2 & 0\\ 0 & \sigma_u^2\end{pmatrix}\right)$$

2. The random components are not correlated with the explanatory variables, that is, for $Z = [D\ G\ X]$ and $\epsilon = [\varepsilon\ u]$, $cov(Z, \epsilon) = 0$

From the assumptions and considering $Z = [1\ D\ G\ X]$, $\theta = [c\ \beta_1\ \delta\ \lambda]'$, $\sigma = [\sigma_\varepsilon^2\ \sigma_u^2]$ and $V = var(Y)$, the log-likelihood function to estimate the parameters of equation 3.3 can be represented as follows:

$$\ell(\theta, \sigma|Y, Z) \propto \frac{1}{2}\left\{\log|\mathrm{V}(\sigma)| + (Y - Z\theta)'\big(\mathrm{V}(\sigma)\big)^{-1}(Y - Z\theta)\right\} \quad (3.4)$$

Thus, the restricted maximum likelihood estimator (RMLE) is given by:

$$\left(\hat{\theta}, \hat{\sigma}\right) = \underset{\theta,\sigma}{\operatorname{argmax}}\, \ell(\theta, \sigma|Y, Z)$$

Further details on the estimation of the multilevel model can be found in De Leeuw *et al.* (2008).

The second specification adopted in this study is given by the inclusion of a third hierarchical level corresponding to the municipality grouping, as shown below:

Level 1 – Time: $y_{tij} = \beta_{0\mathrm{ij}} + \beta_1 D_t + \delta \mathrm{G}_{tij} + \lambda X_{tij} + \varepsilon_{tij}$ (3.5)

Level 2 – School: $\beta_{0ij} = \beta_{0j} + u_{0i}$ (3.6)

Level 3 – Municipality: $\beta_{0j} = \mathrm{c} + u_{0j}$ (3.7)

Replacing (3.6) and (3.7) into (3.5):

$$y_{tij} = \mathrm{c} + u_{0i} + u_{0j} + \beta_1 D_t + \delta \mathrm{G}_{tij} + \lambda X_{tij} + \varepsilon_{tij} \quad (3.8)$$

The vector y and the matrices D, G, and X represent, respectively, the educational institution's IDEB, the temporal dummies, the covariates of education expenses, and the control covariates, similar to the one specified for equation (3.3). In this case, the intercept is divided into three terms, one fixed and two random. The fixed term c is constant over time and equal for schools and municipalities, and the random terms u_{0i} and u_{0j} represent, respectively, the effects of school i and municipality j in relation to the global average c. This new random component, u_{0j}, can be interpreted as a unique effect of the municipality j and is due to the stable characteristics that are not observable of the municipalities.

Finally, a third specification was explored that corresponds to a model with three levels, similar to the previous one, with the inclusion of a random effect of municipality over time, as described below:

$$\text{Level 1 – Time:} \quad y_{tij} = \beta_{0\text{ij}} + \beta_1 D_t + \delta \text{G}_{tij} + \lambda X_{tij} + \varepsilon_{tij} \tag{3.9}$$

$$\text{Level 2 – School:} \quad \beta_{0ij} = \beta_{0j} + u_{0i} \tag{3.10}$$

$$\text{Level 3 - Municipality} \quad \beta_{0j} = \text{c} + u_{0j} \text{ e } \beta_{1j} = \beta_1 + u_{1j} \tag{3.11}$$

Replacing (3.10) and (3.11) into (3.9):

$$y_{tij} = \text{c} + u_{0i} + u_{0j} + \beta_1 D_t + u_{1j} D_t + \delta \text{G}_{tij} + \lambda X_{tij} + \varepsilon_{tij} \tag{3.12}$$

The random term u_{1j} can be interpreted as an individual variation of the municipality j that is not constant in time, that is, this specification predicts an unstable effect of the municipality that varies according to the considered period. The reason behind equation (3.12) stems from the concern with specific factors of each year, which may reach municipalities differently over the years, such as public policies, economic crises, natural accidents, management changes, among others.

Equations (3.8) and (3.12) correspond to extensions of model (3.3) and therefore are subject to the same assumptions and can be estimated in the same way.

3.5 Discussion of Results

This section is dedicated to discussing the research results. In this study, data from a sample of almost 40,000 different schools in the municipal network and that presented the IDEB of elementary school were analysed for at least one of the five years of interest, that is, between 2009 and 2017. About 43% of these schools appear in all five evaluated years, and 62% appear

in at least four years. Considering that, for several reasons, some schools present missing data, each of the years considered counted on a sample of approximately 30 thousand schools. In the Appendix, some descriptive measures can be found for the IDEB and the education investment proxies (Table A.1), as well as for the control variables (Table A.2) used in this study.

Table 3.1 - Variation of the IDEB and actual expenditures per basic school student for the sampled schools (2009-2017)

Indicators	2009 Mean	2017 Mean	Difference	Variation
IDEB	4,29	5,52	1,23	29%
Total current expenditure	4.921,49	7.196,72	2275,23	46%
Total Current expenditure: Personnel and Social Charges	3.535,11	5.305,70	1770,59	50%
Direct current expenditure: Personnel and Social Charges	3.343,50	4.924,16	1580,66	47%
Total Current expenditure: Other	1.385,18	1.889,87	504,69	36%
Direct current expenditure: Other	1.334,20	1.814,84	480,63	36%
Total Capital Expenditures	344,34	277,18	-67,16	-20%
Direct Capital Expenditures	335,17	267,73	-67,45	-20%

Table 3.1 shows the average variation for the IDEB and for the spending proxies per basic school student, between 2009 and 2017. It can be noticed that the average of the IDEB of the municipal schools considered had an advance of almost 30% in the period, from 4.29 in 2009 to 5.52 in 2017. In relation to the variables that correspond to actual expenditures by students, there is an increase in current expenses and a reduction in capital expenditures, which have been observed since the 2015 Brazilians crisis. For example, the average capital expenditure in 2009 was approximately 5.4% of the average current expenditure. In 2013, this proportion reached almost 6%, falling to 5.5% in 2015 and finally plummeting to 3.5% in 2017. It is worth remembering that SIOPE's spending base is dynamic and subject to updates and new expenditure insertions, especially for later years. The total current expenditures increased by 46%, and the variation observed in current expenses with personnel and social charges (around 50%) was higher than the variation observed in other current expenses (36%). Investment expenditures, on the other hand, had a real decrease of approximately 20%.

The correlations between the schools' IDEB and the variables inserted in the models can be checked in Table 3.2. These correlations consider the temporal information (biennial between 2009 and 2017) of municipal schools that offer the primary school and which had information for the considered indicators. The results point to a positive and significant correlation between the IDEB and the expenses with education. For the current expenses (Current, Personnel and Charges, and Other Current Expenses) the correlation coefficient was moderate, being around 0.4. For capital expenditure, the correlation may be considered weak (approximately 0.1).

Table 3.2 - Pearson correlation coefficient between the IDEB of municipal schools and each of the predictor variables inserted in the models

Education Expenditures Per Pupil						
Total applications				Direct applications		
Current	Capital	Personnel and social charges	other current expenses	Capital	Personnel and social charges	other current expenses
0,474**	0,105**	0,424**	0,375**	0,100**	0,400**	0,358**
Control Variables						
Basic infrastructure	Pedagogical resources	Management complexity	Students/teacher rate	Mean of students per class	% of teacher with higher level	Network size
0,404**	0,410**	-0,069**	-0,217**	-0,025**	0,495**	0,088**

** Correlation is significant at the 0.01 level (2-tailed)

Regarding the control variables that represent characteristics of the school, it is observed that the IDEB presents a moderate positive relation with the indicators of basic infrastructure, of pedagogical resources, and of the proportion of teachers with higher level, as expected. Regarding the complexity of management, the correlation was negative, indicating that the quality of the school can be compromised when the management faces bigger challenges, due to a greater complexity in its structure. However, it is important to note that, although significant due to sample size, this correlation was very weak. The average number of students per class and the ratio of the number of students per teacher also showed a negative correlation with the IDEB, indicating that a higher number of students per teacher could mean a deficit of teachers or larger classes and, consequently, could have a negative effect on the IDEB. It is worth mentioning, however, that the correlation between the IDEB and the average number of students per class is very low. Regarding the size of the municipal network in which the school is inserted, there is a positive relationship with the IDEB, suggesting that larger networks would have a positive effect on the quality of the institution. However, the value of the correlation coefficient points to a very weak relationship between these two indicators.

The Table A.3, from Appendix, provides the correlation coefficients between the predictor variables used in this study. It is observed that those coefficients, which appear in the same empirical specification, present weak to moderate correlations. The highest coefficients of correlation were observed between the basic infrastructure and pedagogical resources (0.548), and between the average number of students per class and the students per teachers' ratio (0.565). As there is no strong correlation between pairs of predictor variables in the same specification, there is no evidence of multicollinearity problems for the fitted models.

In order to evaluate whether the municipalities' expenditures have an effect on the IDEB of municipal primary schools, the multilevel model was used as an empirical strategy. The

expenditures were portrayed from three sets of proxies, namely: total expenditures for current and capital expenses; total expenditures for capital expenses, for current personnel and social charges expenses, and for other current expenditure; direct expenses for capital expenditures, for current personnel and social charges expenses, and for other current expenses. Considering these three sets of public expenditure proxies, three different multilevel specifications have been adjusted. The first specification (M1) corresponds to a two-level model with school's random effect in the intercept. The second (M2) is a model with three levels and random effects of school and municipality for the intercept. The third (M3) is similar to the second, but includes a random term of municipality in the time variable. The random effects included in the intercept represent stable effects of schools and municipalities that do not vary over time. However, the random effect inserted in the time variable, at the municipality level, allows the inclusion of an unstable effect of the municipalities that varies over the analysed period. This last random effect was introduced because of concerns about specific year-specific factors (*e.g.*, economic crises and management changes) that could affect municipalities differently over time. All random effects entered in the model were considered significant at the significance level of 0.001.

In order to facilitate the interpretation of the results and allow the comparison of the magnitude of the effects of each variable, they were divided by their respective standard deviation. Table 3.3 presents the results of the adjusted models. In total nine models are presented, and for each of the three sets of spending proxies the three multilevel specifications described have been adjusted. Overall, the results indicate that public spending has a positive and statistically significant effect on the school's IDEB. For all adjustments, the effect of current expenditures, the larger share of education expenditures, was greater than that of capital expenditures. Among the three multilevel specifications, it can be seen that the models M1 and M3 had closer estimated effects, different from the M2 specification, in which the estimated coefficients were much smaller. Taking into account the AIC and BIC information criteria and the log-likelihood, the M3 specification is the most indicated among the three proposals.

Taking the M3 model as a reference and considering the first set of spending proxies, it can be observed that the effect of current expenses was estimated at around 0.10. This means that a positive variation of a standard deviation of current expenses (about R$ 2,500.00 per student) implies an increase in the IDEB equivalent to 10% of its standard deviation (1.2), that is, 0.12 point. It should be noted that R$ 2,500.00 corresponds to approximately 40% of the global average of current expenses. Already 0.12 point represents approximately 2.5% of the global average of the IDEB. This shows that the effect, although significant, is of small magnitude. In relation to capital expenditures, the effect was approximately 0.01, that is, a

variation of a standard deviation in capital expenditures, about R$ 440.00 per student, would have an effect of 0.012 in the IDEB of the school.

In the second specification, which separately measures the effects of current expenses with personnel and charges and other current expenses, it is noted that the estimated coefficient for personnel expenses was slightly higher than that observed for other expenses. A variation of approximately R$ 1,800.00 per student in current staff costs would have an effect of 0.08 point in the school's IDEB. Likewise, a positive variation of approximately one thousand reais in other current expenses would imply an increase of 0.06 in the school's IDEB. The effect of capital expenditure practically did not change in relation to the previous specification. Finally, the third specification, which considers only the expenses with direct applications, had similar results to the one observed in the second one. Overall, these results show that although public education expenditures are systematically positive and meaningful across all specifications, the magnitude of the effects indicates that a very high financial effort is needed to promote the improvement of Brazilian schools. In addition, in a country with very limited resources, it is paramount that this financial effort be accompanied by a detailed evaluation of the effectiveness of public expenditures to identify the factors that have the greatest impact on the quality of education.

In relation to the other variables inserted as controls in the models, it was observed that the indicators of basic infrastructure, pedagogical resources and percentage of teachers with higher level had positive effects on the IDEB. On the other hand, the complexity of management presented an estimated negative coefficient, indicating that schools with a larger number of students, teachers, shifts and stages / modality (that is, schools with a more complex structure) have a negative effect on the institution's results. The estimated effects for these indicators appear to be in line with expectations. In relation to the average number of students per class, there was a positive effect on the IDEB, which seems strange from a pedagogical point of view. However, the literature also does not provide a consensus on this effect. Hanushek's studies indicated that this variable would have no effect on student performance, while Word (1990) concluded that the reduction in the number of students per class in Tennessee/USA had a strong positive effect on student performance. The ratio of the number of students per teacher, as expected, had a negative effect on the IDEB.

Table 3.3 - Multilevel models for ISCED level 1 IDEB in municipal schools, considering the biennial data between 2009 and 2017

	Total Spending						Direct expenses		
	M1	M2	M3	M1	M2	M3	M1	M2	M3
Current	0.138***	0.0410***	0.101***						
	(0.00280)	(0.00320)	(0.00502)						
Current: Personal and Charges				0.0772***	0.0187***	0.0651***	0.0637***	0.0229***	0.0529***
				(0.00248)	(0.00270)	(0.00471)	(0.00226)	(0.00242)	(0.00428)
Current: Others				0.0913***	0.0342***	0.0537***	0.0871***	0.0368***	0.0516***
				(0.00216)	(0.00234)	(0.00378)	(0.00215)	(0.00233)	(0.00367)
Capital	0.00852***	0.00365***	0.00919***	0.00857***	0.00393***	0.00917***	0.00744***	0.00327**	0.00888***
	(0.00142)	(0.00141)	(0.00192)	(0.00142)	(0.00141)	(0.00192)	(0.00142)	(0.00140)	(0.00191)
Basic Infrastructure	0.102***	0.0489***	0.0450***	0.103***	0.0489***	0.0451***	0.104***	0.0490***	0.0451***
	(0.00244)	(0.00220)	(0.00205)	(0.00244)	(0.00220)	(0.00205)	(0.00244)	(0.00220)	(0.00205)
Pedagogical Resources	0.0889***	0.0212***	0.0243***	0.0899***	0.0215***	0.0244***	0.0906***	0.0214***	0.0244***
	(0.00239)	(0.00221)	(0.00208)	(0.00239)	(0.00221)	(0.00208)	(0.00239)	(0.00221)	(0.00208)
Complexity Management	-0.0699***	-0.0501***	-0.0445***	-0.0695***	-0.0500***	-0.0445***	-0.0689***	-0.0501***	-0.0445***
	(0.00271)	(0.00225)	(0.00215)	(0.00271)	(0.00225)	(0.00215)	(0.00271)	(0.00225)	(0.00215)
Student/Teacher	-0.0506***	-0.0150***	-0.00224	-0.0513***	-0.0153***	-0.00228	-0.0516***	-0.0148***	-0.00232
	(0.00239)	(0.00226)	(0.00220)	(0.00239)	(0.00226)	(0.00220)	(0.00239)	(0.00226)	(0.00220)
Average Students per class	0.0334***	0.0397***	0.0201***	0.0332***	0.0395***	0.0201***	0.0332***	0.0397***	0.0200***
	(0.00238)	(0.00223)	(0.00212)	(0.00238)	(0.00223)	(0.00212)	(0.00238)	(0.00223)	(0.00212)
% Teachers with higher level	0.0937***	0.0321***	0.0443***	0.0944***	0.0326***	0.0443***	0.0943***	0.0324***	0.0442***
	(0.00214)	(0.00212)	(0.00212)	(0.00214)	(0.00212)	(0.00212)	(0.00214)	(0.00212)	(0.00212)
Network Size	0.00852**	-0.343***	-0.319***	0.0111***	-0.352***	-0.315***	0.0320***	-0.341***	-0.297***
	(0.00394)	(0.0276)	(0.0708)	(0.00392)	(0.0276)	(0.0707)	(0.00386)	(0.0275)	(0.0712)
Intercept	2.992***	3.308***	3.204***	2.998***	3.305***	3.207***	3.011***	3.284***	3.222***
	(0.0140)	(0.0168)	(0.0186)	(0.0140)	(0.0168)	(0.0186)	(0.0141)	(0.0167)	(0.0187)
Dummies time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
var(Residual)	0.17253	0.16404	0.11286	0.17263	0.16401	0.11287	0.1721	0.16396	0.11287
School: var(Intercept)	0.46255	0.12135	0.13126	0.45782	0.12136	0.13125	0.4654	0.12132	0.13126
Municipality: *var(Intercept)*		0.53502	0.47382		0.52923	0.47228		0.52522	0.47908
Municipality: *var(time)*			0.05869			0.05869			0.05856
N	144341	144341	144341	144341	144341	144341	144341	144341	144341
AIC	246525.7	212167.7	190515.1	246236.7	212106.7	190517.7	246480.4	212032.0	190556.0
BIC	246683.7	212335.6	190692.9	246404.7	212284.5	190705.4	246648.4	212209.9	190743.7
Log lik.	-123246.8	-106066.8	-95239.5	-123101.4	-106035.3	-95239.9	-123223.2	-105998.0	-95259.0

Notes: (1) Standard error in parentheses. (2) M1 refers to the two-level multilevel model with random intercept (3) M2 refers to the three-level model with random intercept (4) M3 refers to the three level model with random component for the intercept and for the variable year. (5) All indicators were divided by their respective standard deviation. (6) *$p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*

The models also had a control variable that represents the size of the municipal school network in which the school is inserted. It is observed that in the models with only two levels (time and school), the effect of this variable was considered positive, indicating that larger networks would have a positive effect on the IDEB. For the other two models, which have the insertion of a third hierarchical level (municipality), the size effect became negative, *i.e.*, considering inter-municipal differences, larger networks imply a decrease in the IDEB.

Finally, Table 3.3 also presents the variance estimate of the random error terms. From these estimates it is possible to calculate the proportion of the variability that is due to the observed differences between each of the hierarchical levels. For models with two hierarchical levels (M1), it is verified that the variance estimates for the second hierarchical level were higher than 0.45, while for the first level the estimates were 0.17. This shows that little more than 70% of the variability observed for the IDEB over time is due to differences between schools. With the insertion of the third level (municipalities), there is a considerable reduction in the variance estimates of the second hierarchical level (school). For the M2 models, the variance components were estimated at approximately: 0.16 for the level 1 (time); 0.12 for the level 2 (school); and 0.53 for the level 3 (municipalities). For the M3 specification, the components of variance were estimated at about: 0.11 for the level 1 (Time); 0.13 for the level 2 (school); and 0.47 for level 3 (municipalities). For all the models with three hierarchical levels (M2 and M3), the results reveal that approximately 65% of the variation in the IDEB over time is due to differences between municipalities[27]. These results reinforce not only the importance of using a multilevel structure, but also the inclusion of the third hierarchical level, since the effect of the municipality on the school's IDEB over time is quite high.

3.6 Final remarks

For this study, a series of limitations and problems was present, especially regarding the unavailability, non-existence or complexity of the data used. For example, mappings on the specific destination of the municipality's expenditures with education, or reliable municipal indicators of the efficiency of the management of these funds, don't exist or are unavailable.

[27] It is important to note that the adjusted models rely on only one control variable with characteristics of the municipalities, which helps explain in part the high estimated variance of the error term of the third hierarchical level. Other specifications that included more controls of municipality were tested. However, although they reduced some of the estimated portion of the variance that was due to the differences between municipalities, there was a considerable sample loss and a reduction in the evaluated period. It was decided not to include the results of these adjustments since they had effects similar to those observed in the Table 3.3, especially with respect to the estimated effects for municipalities' expenses.

Regarding the quality of the information, some problems were detected in the financial and educational data. Regarding the financing data, it was found that for a considerable number of municipalities, the sums of expenditure items disaggregated at their minimum levels were not compatible with the total expenditure, which made it impossible to identify the specific expenses with MDE, proxy initially thought for spending on education. Regarding educational data, most of the schools offering ISCED 1 were not considered in this research, since they did not present IDEB values. Although the IDEB is the main indicator for evaluating the quality of educational institutions, schools that do not have at least 20 students enrolled in regular classes in the 5th year are not eligible to participate in the *Prova Brasil*/Saeb and therefore will not have their IDEB calculated for that year. The final sample counted on the participation of approximately 35% of the schools offering primary education and sums more than 70% of the students at this stage.

Problems of fragility and unavailability of data become more serious in the light of statistical analysis. The loss of schools and municipalities in the sample and possible inconsistencies in the provided information should be intuitively related to the lack of resources of smaller municipalities, which have the most precarious teams and systems to fill out registration information. In addition, because they are compulsory expenses by law, there may be municipalities with less interest in providing reliable information.

Another important limiting aspect to be considered is the short period of longitudinal data available for the proposed type of assessment. Benefits from educational investments are often only measurable in the medium and long term, respecting the student's time of exposure to new resources and the cycle of preparation and replacement of professionals after new educational policies implementation. Because large-scale assessments are generally carried out at the end of long cycles, students attending examinations in the fifth and ninth grades of elementary school have been exposed to educational systems created five or nine years earlier, and most of their teachers have graduated or opted for that career for much longer than that. It seems reasonable to assume that changes in education investments are more easily perceived and better estimated in the medium and long term.

Despite the limitations found, this study shows that there is a positive and significant relationship between education expenditures and the IDEB of municipal schools. Although the estimated effects are relatively small, one should consider the investment margin Brazil still has, not only in relation to the percentage of GDP spent on education, but mainly in terms of spending per student. For example, the average expenditure per elementary and high school

student in Brazil for 2015 was USD 3,872.00, about 40% of the average expenditure per student of the OECD member countries (USD 9,868.00), according to OECD (2018).

Finally, the values of public spending on education had a small effect on the IDEB, certainly much lower than external factors such as the family background or the socio-economic profile of the community served by the school. In spite of this, one must consider, from the point of view of public management, the investment in education as one of the main forms of direct intervention on the quality of the educational system. However, it is clear that the simple gross increase in spending on education will not be enough. There is a need for better monitoring the management of these resources and a more detailed evaluation of the effectiveness of expenditure. In addition, the articulation and commitment of the institutions responsible for the educational system may contribute to the conversion of these financial resources into an increase in the quality of education. Improvement in the student's learning process needs to be seen as part of a virtuous cycle as this student is the future member of a family that will, potentially, positively influence a new student's learning process, this time as an element of the family background.

4. CONCLUSION

This study, composed of empirical essays, intends to bring contributions to the literature that deals with the quality of education. The first essay, conducted at the individual level from PISA data, assesses whether the cognitive abilities of Latin American students are affected by variables linked to three major dimensions: the characteristics of the individual, the family background, and school supplies.

Due to the hierarchical structure present in the data of educational evaluations, it was decided to use a multilevel approach. This technique is well suited for this type of structure, since it allows quantifying the effect of schools on student outcomes. In addition, the stratification imposed by the sample plan may lead to the endogeneity bias in multilevel strategies, since the student profile and characteristics of the school community may be correlated. To correct such problems, the characteristics of the students aggregated by educational institutions were inserted, as indicated in Hanchane and Mostafa (2012).

The results indicate that the characteristics of the student and his/her family are fundamental aspects to explain the performance of the pupil, being these factors systematically significant in every adjustments made. Another important determinant of academic success is the peer effect, built from aggregations of student information per educational institution to portray the profile of the school community. The inclusion of these effects, besides contributing to improve the quality of the adjustments, are also relevant factors to explain the students' results. Regarding school supplies, the factors that presented the most robust results were the classroom disciplinary climate and the existence and adequacy of the pedagogical resources.

The results also show that a considerable part of the variation observed in the students' grade is due to the differences between the schools, which reinforces the need to use the multilevel strategy. The high estimates of the school effect for Latin countries make clear the importance of the educational institution in terms of student performance. Although robust results have not been found for some of the tested school supplies, there is strong evidence of the school's effect on student success.

The second essay deals with a longitudinal study, with the objective of verify if the public expenditure on education of the Brazilian municipalities contributes to improve the quality of schools of the municipal network. For a methodological approach, multilevel models were applied to biennial data from 2009 to 2017. The Basic Education Development Index (IDEB) of municipal schools was used as a proxy for the quality of schools. The municipalities' expenses, derived from the SIOPE, were broken down into current expenses and capital

expenditures. All adjusted specifications relied on control variables that portrayed characteristics of schools and the municipal network.

The adjustments made provide evidence that both current and capital spending on education has positive effects on the IDEB. However, although these effects are significant in all models, the magnitudes observed are much smaller than factors external to the school (*e.g.* family background or the socioeconomic profile of the community attended by the school). This result shows that the simple increase in education spending is not enough to overcome the educational delay observed in the country. It is essential that there is better monitoring of the management of these resources and a more detailed evaluation of the effectiveness of expenditure. In addition, the articulation and commitment of the institutions responsible for the educational system may contribute to the conversion of these financial resources into an increase in the quality of education.

Finally, despite of this small effect of public expenditure on the IDEB, it should be considered that investment in education is one of the main forms of direct intervention on the quality of education, from the point of view of public management. Improvement in the student learning process needs to be seen as part of a long term virtuous cycle, since a today's pupil someday will be the member of a family who should positively influence a future student learning process, this time as an element of the family background.

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APPENDIX

Table A.1 - Descriptive measures for the IDEB and the indicators of expenditures on basic education in the municipalities. Period from 2009 to 2017

		Valid N	Mean	Standard Deviation	First Quartile	Median	Third Quartile
IDEB - ISCED 1 - Municipal Schools	2009	29.741	4,29	1,07	3,50	4,30	5,10
	2011	28.473	4,65	1,06	3,90	4,60	5,40
	2013	27.995	4,82	1,16	4,00	4,80	5,70
	2015	28.887	5,21	1,10	4,40	5,20	6,00
	2017	29.245	5,52	1,12	4,70	5,60	6,30
Current expenditure on basic education per student	2009	29.741	4.921,49	2.021,10	3.389,34	4.463,80	5.940,91
	2011	28.473	5.606,96	2.329,64	3.881,80	5.024,06	6.877,04
	2013	27.995	6.382,20	2.473,80	4.487,41	5.838,57	7.808,35
	2015	28.887	6.952,33	2.549,51	4.952,90	6.399,27	8.446,30
	2017	29.245	7.196,72	2.396,86	5.323,58	6.841,44	8.697,81
Current expenses with staff and social charges in basic school per student	2009	29.741	3.535,11	1.460,63	2.496,97	3.154,14	4.168,28
	2011	28.473	4.025,87	1.683,81	2.853,73	3.687,85	4.728,28
	2013	27.995	4.778,53	1.822,69	3.451,45	4.422,89	5.705,57
	2015	28.887	5.029,19	1.862,33	3.642,45	4.606,43	6.057,76
	2017	29.245	5.305,70	1.724,30	4.013,84	4.995,97	6.434,37
Current expenses with personnel/social charges in direct applications on basic school students	2009	29.741	3.343,50	1.349,54	2.443,06	3.012,14	3.817,06
	2011	28.473	3.690,37	1.380,02	2.748,09	3.445,31	4.295,26
	2013	27.995	4.445,61	1.624,47	3.296,22	4.194,19	5.149,76
	2015	28.887	4.666,61	1.676,11	3.484,41	4.322,59	5.470,87
	2017	29.245	4.924,16	1.507,19	3.812,93	4.704,63	5.733,26
Other current expenditure on basic education per pupil	2009	29.741	1.385,18	913,11	784,48	1.118,01	1.678,49
	2011	28.473	1.579,89	1.040,61	859,55	1.323,10	2.060,82
	2013	27.995	1.602,55	1.056,79	871,30	1.334,30	2.005,99
	2015	28.887	1.922,12	1.153,25	1.163,08	1.588,82	2.399,60
	2017	29.245	1.889,87	1.172,93	1.074,00	1.623,15	2.374,55
Other current expenditure on basic education in direct applications per student	2009	29.741	1.334,20	899,15	766,30	1.059,29	1.600,60
	2011	28.473	1.486,13	967,71	847,82	1.269,14	1.859,35
	2013	27.995	1.519,87	997,67	849,94	1.252,75	1.966,28
	2015	28.887	1.854,45	1.108,51	1.111,10	1.540,90	2.324,39
	2017	29.245	1.814,84	1.126,71	1.036,87	1.564,09	2.332,62
Capital expenditure on basic education per pupil, lagged in one period	2009	29.741	344,34	441,99	90,95	207,62	445,27
	2011	28.473	301,25	379,40	80,43	187,63	374,98
	2013	27.995	395,67	513,03	83,03	250,65	516,70
	2015	28.887	304,17	441,56	69,52	186,60	389,17
	2017	29.245	277,18	397,30	52,36	145,42	355,71
Capital Expenditure in the form of direct applications in basic education per student, lagged in one period	2009	29.741	335,17	437,84	78,65	198,13	439,40
	2011	28.473	290,30	375,61	76,43	181,24	359,72
	2013	27.995	385,24	509,02	76,03	245,09	502,79
	2015	28.887	294,95	438,63	63,62	165,56	380,79
	2017	29.245	267,73	395,22	47,35	133,12	342,15

Table A.2 - Descriptive measures for control variables. Period from 2009 to 2017

		Valid N	Mean	Standard Deviation	First Quartile	Median	Third Quartile
Factor: basic infrastructure	2009	29741	0,86	0,61	0,40	0,79	1,15
	2011	28473	1,00	0,62	0,77	1,15	1,55
	2013	27995	1,07	0,63	0,77	1,15	1,56
	2015	28887	1,13	0,63	0,77	1,17	1,58
	2017	29245	1,10	0,66	0,77	1,17	1,58
Factor: pedagogical resources	2009	29741	0,57	1,02	-0,16	0,52	1,24
	2011	28473	0,84	0,94	-0,09	1,17	1,24
	2013	27995	0,98	0,90	0,49	1,17	1,89
	2015	28887	1,02	0,89	0,49	1,17	1,89
	2017	29245	0,91	0,90	0,49	1,17	1,89
Factor: complexity of school's management	2009	29741	0,91	1,02	0,16	0,75	1,47
	2011	28473	0,92	0,99	0,18	0,75	1,46
	2013	27995	0,90	0,97	0,19	0,73	1,44
	2015	28887	0,87	0,95	0,16	0,69	1,40
	2017	29245	0,73	0,91	0,06	0,54	1,21
Student/teacher ratio	2009	29741	23,39	7,09	18,50	22,50	27,27
	2011	28473	22,10	6,50	17,60	21,33	25,59
	2013	27995	20,52	6,25	16,20	19,76	23,90
	2015	28887	19,82	6,02	15,62	19,11	23,12
	2017	29245	18,42	6,19	14,13	17,75	21,85
Mean of students/class – ISCED 1	2009	29741	24,56	4,71	21,30	24,50	27,70
	2011	28473	23,92	4,36	20,90	23,80	26,80
	2013	27995	23,31	4,21	20,40	23,20	26,10
	2015	28887	23,35	4,08	20,50	23,30	26,10
	2017	29245	22,20	4,86	19,10	22,40	25,50
Proportion of teachers with higher education – ISCED 1	2009	29741	60,01	32,34	33,30	66,70	87,50
	2011	28473	65,52	29,81	44,40	73,30	90,00
	2013	27995	74,12	26,47	60,00	83,30	95,20
	2015	28887	76,55	24,89	63,20	84,60	96,80
	2017	29245	79,59	23,41	69,20	87,50	100,00
Factor: size of the municipal school network	2009	29741	2,72	8,21	-0,03	0,40	1,43
	2011	28473	2,87	8,37	-0,02	0,43	1,58
	2013	27995	2,16	6,45	-0,03	0,40	1,64
	2015	28887	2,87	8,27	-0,03	0,45	1,77
	2017	29245	2,62	8,00	-0,07	0,33	1,51

Table A.3 – Pearson correlation's coefficient between predictor variables

	Total: current	Total: capital	Total: current personal and charges	Total: current others	Direct: current personal and charges	Direct: current others	Direct: capital	Basic infrastructure	Pedagogical resources	Complexity management	Student/ teacher	Mean of students /class	Teachers with higher level (%)
Total: Capital	0.137**												
Total: Current Personal and Charges	0.920**	0.077**											
Total: Current Others	0.750**	0.184**	0.430**										
Direct: Current Personal and Charges	0.880**	0.091**	0.957**	0.412**									
Direct: Current Others	0.716**	0.196**	0.399**	0.974**	0.401**								
Direct: Capital	0.132**	0.994**	0.072**	0.183**	0.087**	0.196**							
Basic Infrastructure	0.345**	0.048**	0.351**	0.203**	0.307**	0.174**	0.042**						
Pedagogical Resources	0.354**	0.067**	0.353**	0.220**	0.311**	0.189**	0.061**	0.548**					
Complexity Management	0.029**	-0.035**	0.053**	-0.022**	0.020**	-0.049**	-0.038**	0.254**	0.329**				
Student/Teacher	-0.264**	-0.068**	-0.260**	-0.169**	-0.300**	-0.180**	-0.066**	-0.041**	-0.131**	0.089**			
Students per class (mean)	-0.063**	-0.045**	-0.053**	-0.055**	-0.123**	-0.082**	-0.047**	0.215**	0.106**	0.315**	0.565**		
Proportion of Teachers with higher level	0.423**	0.071**	0.393**	0.310**	0.370**	0.291**	0.068**	0.385**	0.386**	0.036**	-0.123**	0.030**	
Network Size	0.340**	-0.040**	0.358**	0.179**	0.174**	0.130**	-0.041**	0.174**	0.137**	0.157**	0.150**	0.294**	0.116**

**. Correlation is significant at the 0.01 level (2-tailed).

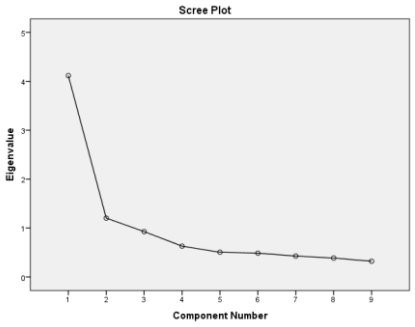
Figure A.1 - Control variables from the factorial analyses applied to the school census data.

Factor - Basic infrastructure

Correlation between the random vector and the first factor

	Factor1
Public electric network	0.525
Public electric network	0.759
Public sewer network	0.659
Regular garbage collect	0.83
Principal's room	0.743
Teachers' room	0.739
Bathroom inside the building	0.591
Disabled people bathroom	0.615
Disabled people dependencies	0.561

Factor1 represents 45.7% of the total variation.



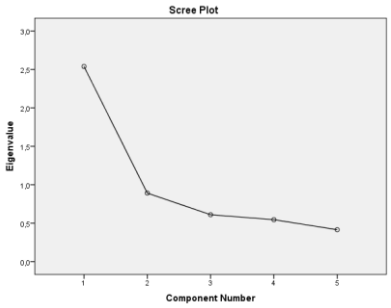
P-value to the Bartlett's test < 0.001

Factor - Pedagogical resources

Correlation between the random vector and the first factor

	Factor1
IT labs	0.784
Science labs	0.427
Sports court	0.763
Library	0.723
Internet access	0.798

Factor1 represents 50.8% of the total variation.



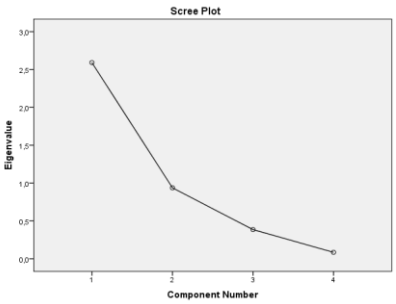
P-value to the Bartlett's test < 0.001

Factor - Complexity of school's management

Correlation between the random vector and the first factor

	Factor1
Number of enrolments	0.879
Number of levels/mode	0.630
Number of turns	0.794
Number of teachers	0.890

Factor1 represents 64.8% of the total variation.



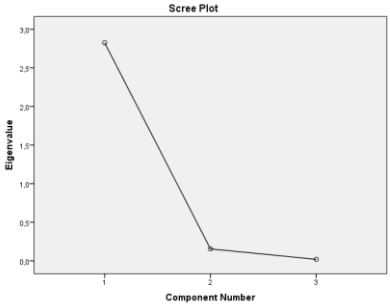
P-value to the Bartlett's test < 0.001

Factor – Size of the municipal school network

Correlation between the random vector and the first factor

	Factor1
Number of Schools	0.946
Number of Students	0.983
Number of teachers	0.983

Factor1 represents 94.2% of the total variation.



P-value to the Bartlett's test < 0.001