Higher Salaries, More Teaching, Better Performance?*

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Abstract

The empirical literature has produced strong evidence that, after controlling for pupils' socioeconomic characteristics, teacher quality is the most important school factor in explaining pupil's performance in standardized tests. However, there is no consensus on how public school systems could improve teacher quality. The objectives of this paper are twofold. The first objective is to estimate the impact of raising teachers' salaries on students' proficiency using the exogenous increase in municipal teacher's salaries triggered by the introduction of a national minimum salary for public school teachers in Brazil. To circumvent limitations of existing databases, we carried out a survey with municipal education departments to get information about teachers' salaries and career structures. Municipalities whose teachers' salaries were below the national minimum experienced larger teachers' salary increases than the others between 2008 and 2011. The second objective is to assess transmission channels through which higher salaries could lead to better pupils' performance. Mainly, the recruitment and/or retention of most skilled teachers and the reduction of the number of teachers who combine teaching with other paid jobs. We use difference-in-differences methods to control for fixed effects and propensity score matching to balance treatment and comparison groups and, alternatively, an instrumental variable approach. The policy had no effect on 5th graders proficiency in its first year of execution and a mild effect after its third year. However, no transmission channel was identified.

Keywords: Impact evaluation; teachers' minimum salary; teachers' quality; pupils' performance.

JEL Classification: I21; I28; C31; J45.

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1 Introduction

Poor quality education has very serious consequences. There is strong evidence that what individuals actually learned at school, not their years of schooling, explains differences in economic growth rates between countries[4]. After controlling for pupils' socioeconomic background, the most important school factor in explaining pupils' performance in standardized tests is teacher quality[5]. Studies also show that improving teacher quality could significantly raise the performance of low-scoring students[6]. At the same time, teachers pay is the largest single budget item of any school system. In Brazilian municipalities, for instance, about 60% of the education budget is spent with teachers' payroll or is supposed to be, considering Constitutional imposition[7].

Thus, an important policy issue is how countries can increase the quality of teachers. Several studies concluded that teacher quality is not explained by observable characteristics in terms of experience and schooling, but mainly by unobservable characteristics[8], making it even harder to promote teacher quality, particularly in public schools. Do higher salaries not linked to a pay for performance scheme yield better teachers? A pre-requisite to properly address this question is a source of exogenous variation in salaries. We explore the introduction of minimum salary for Brazil's public school teacher as an exogenous shock driving up teachers' salaries in some municipalities. The main goal of this paper is to estimate the impact of raising the salary of public schools teachers on the quality of education, measured by students' performance in standardized tests.

After an expressive increase in education coverage during the last two decades in Brazil, the current challenge is to expand the quality of basic education. International proficiency tests show that Brazilian students underperform relatively to students from other countries that spend similar amounts in education in terms of per capita GDP, such as

[4] Hanushek and Kimko (2000); Hanushek and Woessmann (2008, 2012).

[5] According to Hanushek et al (2005), students with a teacher in the 85th percentile of teacher quality distribution outperform students with a teacher at the median of teacher quality distribution by 0.22 standard deviations. Additionally, Rockoff (2004) shows that a one-standard-deviation increase in teacher quality raises test scores by approximately 0.1 standard deviations in reading and math on standardized tests and Rivkin et al (2005) concludes that teacher quality impacts on academic performance of her/his students more than other inputs. For instance, a one-standard-deviation increase in teacher quality impacts more on students' scores than a costly reduction of 10 students in class-size. In the Brazilian context, Moriconi (2012), using value added data for the municipality of São Paulo, concludes that the variation of teacher effectiveness explains about 9% of all the students test scores variability, in a lesser degree than the variability in socioeconomic characteristics (15%), but in a higher degree than the variability in school characteristics (5%). She estimates that teacher effectiveness one standard deviation higher would increase students test scores in between 0.062 and 0.31 standard deviation in Portuguese, and between 0.049 and 0.308 standard deviation in Mathematics.

[6] Chetty et al (2013).

[7] According to *Controladoria-Geral da União* (*CGU*), the Brazilian Federal Internal Control Agency, of 124 auditing done (120 municipalities and 4 states), despite the imposition by the Brazilian Constitution, only 83 sub-national governments observe this rule, about 2/3 of those scrutinized school systems, though.

[8] Hanushek (1986), Hanushek and Rivkin (2006, 2010).

Mexico, Chile and Thailand[9]. In Brazil, teacher salaries are lower than in alternative occupations, and there is evidence that poor performing students are attracted to teaching profession (INEP, 2009 and 2010). But after the introduction of the teacher minimum salary, there has been a noticeable increase in the real salary of municipal teachers.

Theoretically and empirically, there are many factors influencing the teacher's (or any employee's) effort[10]. Microeconomic theory states that more effort is associated to higher costs. So, in order to put more effort in an activity or task, the agent needs to be properly compensated. There are at least two channels through which higher salaries could affect teaching quality. Firstly, better paid teachers can devote more time or effort to teaching activity, for instance, allocating more time to the preparation of lessons[11]. Similarly, some teachers may quit other secondary paid job that they may have and dedicate more time to teaching activities. Furthermore, teachers would be less tired and stressed when performing their work. Consequently, they would become much more productive. This channel is much more difficult to test as teachers' effort and time devoted to teaching activities are difficult to observe or measure. We test the effect of salary hikes on the proportion of full-time teachers and other indirect sources of teacher effort. There is a vast literature assessing the effects of performance based payments on teachers' effort, but, to the best of our knowledge, there are no studies testing such effect when salaries are raised linear and unconditionally.

The second channel is related to recruitment and retention of more effective teachers, i.e. to changes in extensive margin of teacher quality. Results from a large empirical literature indicate that salaries paid to teachers are negatively related to their propensities to exit teaching and positively related to durations in first teaching positions[12]. Intuitively, a necessary condition for attracting high quality teachers is offering higher salaries and/or better work conditions. This condition is not sufficient since less motivated workers are

[9] In PISA 2012, for example, Brazil appeared at the low bottom of the list of 65 countries, behind those three countries.

[10] Among these factors, the economic literature presents evidence that higher unemployment rates are associated with higher levels of effort among employees. See Blinder and Choi (1990) and Agell and Lundborg (1995).

[11] There are evidences from Experimental Economics that higher wages are associated with greater level of effort on the part of employees. Fehr, Kirchsteiger and Riedl (1993) and Fehr and Falk (1999) reported experiments in which participants in the role of employees showed less effort when receiving lower wages even when the lesser effort entailed greater cost to themselves. Moreover, the preference for fairness or reciprocity induces workers to work harder in response to higher wages (Akerlof and Yellen 1990). Field and laboratory experiments indicate that this response tends to be greater the more common are feelings among workers of unfair treatment by employers. As teacher salary in Brazil is considered low, it is likely that the feeling of injustice among workers would be common. Thus, it may be that gift exchange effects occur when teachers' salaries are raised. (Fehr et al, 2009)

[12] See Dolton and van der Klaauw (1999) and Behrman et al (forthcoming) that present a brief survey on this literature. More related to our approach, Falch (2011) examines the effect of salaries on teacher leaving decisions using a natural experiment approach. In Norway, teachers in schools with a lot of prior teacher vacancies received a salary premium of about 10 percent during 1993-94 to 2002-03. Using a school fixed effects model, he finds that the salary premium reduces the probability of voluntary quits by six percentage points.

induced to apply for the vacancy by higher salaries too[13]. That intuition was confirmed by an experiment in Mexico. Dal Bó et al (2013) find that higher wages attract more able applicants as measured by their IQ, personality, and public service motivation. Thus their results are against the hypothesis of adverse selection[14]. Besides, they find that distance and worse municipal characteristics strongly decrease acceptance rates, but higher wages help bridge the recruitment gap in municipalities characterized by worse work conditions.

Does the same phenomenon happen when the public sector is recruiting teachers? The literature that estimates the relationship between financial incentives and measures of teacher aptitude finds a positive correlation. There is evidence that high quality teachers respond to financial incentives such as bonuses payment based on performance. However, in the absence of pay for performance schemes, Behrman et al (forthcoming) simulations based on their estimated model show that increasing the Chilean municipal teachers wage by 20% would increase the number of certified teachers, but would not increase the "quality" of teachers employed, as the higher wage also would attract lower productivity types into the teaching profession[15]. This result corroborated Mansky (1987) who concluded that, in the absence of a minimum ability standard, increases in teacher earnings would yield higher teaching force recruitment but minimal improvement in the average academic ability of teachers. According to Mansky (1987), only the imposition of a minimum ability standard combined with sufficient salary increase would improve average teacher ability.

According to Metzler and Woessmann (2012), one of the few teacher attributes that is correlated with the performance of students are the academic skills of teachers, as measured by performance on standardized tests. Guimarães et al (2013), in Brazilian context, find evidence that teachers with higher content knowledge have a greater impact on the math test scores of their students, an effect that is even larger at the school-level. Fernandes (2013) corroborated the relevance of teacher's content knowledge to explain pupils' performance with a different dataset for a different region of Brazil. Several studies show that higher wages lead to raising quality of teachers as measured by their scores on standardized tests such as the SAT[16], or cause the increase of the students' scores[17].

[13] As put by Dal Bó et al (2013), particularly in the context of public service, two characteristics of a candidate would promote performance: her/his ability to perform (denominated by authors as "raw quality") and her/his desire to perform.

[14] As in Delfgaauw and Dur (2007).

[15] As stressed by the authors, the main distinction between municipal wage offers and private schools wage offers is that the municipal sector has a rigid schedule in which everyone is paid according to their teaching experience and not according to teaching ability. Their simulations show that setting the municipal wage schedule equal to the wage offer function used in the private voucher sector, which distinguishes among productivity types, would generate increases in teacher quality within the municipal sector, at the expense of lower teacher quality in the private voucher sector.

[16] Such as Ballou and Podgursky (1995) and Stinebrickner (2001).

However, the positive effect of salary increases not based on performance is more controversial. This paper's findings contribute to this debate.

In this paper we take advantage of an exogenous increase of teacher salaries due to the introduction of a mandatory teacher minimum salary in 2008 by the Brazilian federal government, and estimate the impact of salary hikes on pupils' test scores. Before the reform, municipal school systems used to set salaries autonomously. In this version of the paper we discuss the results for 5th grade pupils obtained through difference-in-differences methods combined with propensity score matching. Municipalities whose teachers' salaries were below the national minimum when the law was enacted experienced larger teachers' salary increases than the others between 2008 and 2009. The former raised salaries on average by 23.3% whereas the latter group raised salaries by 8.5%[18]. Unfortunately we could not get each teacher salary and link teacher salary to classes and see her/his pupils' performance in standardized tests. Therefore we have to work with the average teacher salary of each municipal school system and the average pupil test scores in Mathematics and Portuguese. The method allows us to estimate the impact of undertaking the treatment defined as raising salaries in order to comply with the law.

We compare treated units with different comparison groups, and could not reject the hypothesis of a null effect of the treatment on pupils' proficiency in the first year of the policy. However, one would argue that one year is not enough to reveal all policy potentialities and effects should come in a near future. Then we further estimate the impact of the policy using pupils' 2011 test scores. For this purpose, besides the DID method we explore an IV approach.

Understanding the transmission channels through which higher wages could lead to better pupils' performance is another important issue. A vast literature shows that higher relative teachers' salaries increase the likelihood that an individual enters the teacher profession and reduce the likelihood that a teacher leaves the profession[19]. Also, Imazeki (2005) found that teacher transfers between school systems respond most strongly when district salaries are increased relative to nearby districts. Furthermore, Leigh (2012) models the relationship between current teacher salaries and the academic aptitude of potentially future teachers, seen as those who were entering teacher education courses and finds that a

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[17] See Hanushek et al. (1999) and Menezes-Filho and Pazello (2007). Menezes-Filho e Pazello (2007) pointed out the better retention and recruitment, afforded by salary raise, as a probable cause for the positive estimated effect on students test scores.

[18] As a reference, the accumulated Brazilian economy inflation was about 5.9% in 2008.

[19] Chevalier et al (2007), Zabalza et al. (1979), Dolton (1990), Dolton and van der Klaauw (1995 e 1999), and Dolton and Mavromaras (1994) for the United Kindom; and Stinebrickner (1998), Brewer (1996), Rees (1991), Mont and Rees (1996), Murnane and Olsen (1989 e 1990), Theobald (1990), and Theobald and Gritz (1996) for the United States.

1 per cent rise in the salary of a starting teacher boosts the average aptitude of potentially future students by 0.6 percentile ranks.

Even though after almost three years of the introduction of the policy we find just a slight effect of the policy on pupils' performance on tests, with 10% of significance level, it is possible that impacts are yet to be revealed after the operation of some transmission channels which need more time to take place. So, in addition, we investigate two kinds of transmission channels through which higher salaries could lead to better pupils' performance. Namely, the recruitment and/or retention of most skilled teachers and the reduction of the number of teachers who combine teaching with other paid jobs. When we compare treated units with never-takers we find a statistically significant positive impact of the treatment on the proportion of full-time teachers but no effect on teachers' scores during college.

The rest of the paper is organized as follows. Section 2 presents some relevant institutional features of Brazilian municipal school systems. Section 3 discusses the data used in this paper, and Section 4 shows some descriptive statistics. The methodology and identification strategy are described in Section 5 and results are shown in Section 6. Section 7 concludes.

2 Institutional Background

Brazil is a federation with three government levels: federal, 27 state governments (one of which is a Federal District) and 5,564 municipalities. Brazil's Constitution states the responsibilities of each government level in guaranteeing public and free education for all their citizens. Specifically, municipalities must provide day-care, pre-school and primary education for their inhabitants.

More broadly, the Brazilian public basic education system is characterized by a decentralized nature and by a federal funding scheme. Each of these government actors has its own public educational system and is responsible for its maintenance and for the administration of its funds and financial resources. In 2012 there were 50.5 Millions Brazilians at school. According to *INEP* (2012), Brazilian municipal school systems were responsible for 45.9% of the enrolments in primary and secondary education and state school systems for 37.5%, showing the predominant role of public sector in providing basic education in Brazil. Mainly, municipalities offer day-care (63.1% of the enrollments), pre-school (74.2% of the enrollments), and from the 1st grade to the 5th grade of elementary school (68.2% of the enrollments). On the other hand, municipalities provide lower secondary education to just 39.5% of the students and their role is even smaller considering high school provision, with only 0.9% of the enrollees. Thus the focus of this study is on

municipal school system and consequently on the primary school, corresponding to the 5 first years of schooling, stage predominantly provided by municipalities.

A federal funding scheme guarantees a minimum amount of resource per pupil in each municipal and state school system. The Constitution reserves 25% of state and municipal taxes and 18% of federal taxes for education. Most part of these resources makes up a fund, *FUNDEB*[20], in each state of the federation. Its resources distribution across public school systems is based on the quantity of pupils in each system[21]. Accordingly to the Constitution, at least 60% of the *FUNDEB* resources have to be spent with salaries of teachers and other professionals directly involved in teaching activity. Furthermore, each municipality is supposed to have a Municipal Council for Social Monitoring and Control of *FUNDEB*, a board composed of members of the government and the civil society[22] which has as its main duty to monitor and to control the distribution, transfer and use of resources from *FUNDEB* in the local context.

Brazilian municipal school systems employ 1.07 million teachers, 471,266 teach in primary school (62.4% of the total primary teachers) and 355,669 teach in lower secondary school (41.2% of the total secondary teachers). Considering that the total amount of all *FUNDEB* funds transferred to municipalities in 2012 summed R$ 64.88 billions, it is presumed that approximately R$ 38.93 billions were paid to municipal school teachers and other school staff directly involved in teaching activities in 2012. Since the introduction of the teacher minimum salary in public schools, mean teacher salary in municipalities which complied with the law had grown nearly 19 p.p. more than in municipalities that do not follow the law (85.9% against 66.8%).

The decentralized nature of Brazilian public basic education system gives great organizational autonomy to sub-national governments in managing their educational systems. The maintenance of the system, including the definition of teacher career and payment structures and school curriculum content are decentralized. Therefore municipal teachers' salaries are decided by local governments. Until January 2009, the municipalities had established the salary of teachers independently of the Federal Government. After

[20] Portuguese acronym for *Basic Education Maintenance and Development Fund* (*Fundo de Manutenção e Desenvolvimento da Educação Básica e de Valorização dos Profissionais da Educação*). Roughly 20% of municipal and state taxes are allocated to *FUNDEB*. Apart from *FUNDEB*, according to the Brazilian Constitution, municipalities also have to spend in education 25% of their own collected taxes in education, and 5% of the bunch of taxes associated to *FUNDEB*.

[21] Federal government supplements state *FUNDEB* when is necessary to guarantee the minimum national value of resources per pupil. Consequently the discrepancy of the amount of resources per pupil between states is reduced after federal supplements. Since 2010, the total amount transferred by federal government to the 27 *FUNDEB* (one fund for each state and the Federal District) corresponds to 10% of the total resources put in *FUNDEB*.

[22] Two representatives of the Executive Power of the Municipality; one representative of the teachers of the public school system; one representative of school principals; one representative of the administrative staff of the elementary and/or high schools; two representatives of parents of students; and two representatives of students, at least one of them indicated by the high school students association.

passing the Law No.11,738, of July 16th, 2008, the Federal Government began to set the minimum amount to be paid as base salary of the teachers of all public school systems[23]. However, as will be discussed in the next sections, only part of the municipalities complies with the minimum base salary.

In October 2008, soon after the minimum wage law was enacted, the governors of five states, Mato Grosso do Sul, Paraná, Santa Catarina, Rio Grande do Sul, and Ceará, questioned the constitutionality of the law[24]. On April 6th, 2011, the Brazilian Supreme Court decided for the constitutionality of the law. There is a possibility that some municipalities and states waited for the Supreme Court decision and did not comply with the minimum salary until then. Therefore another point in time of compliance with the law would be expected. However, our analysis will be restricted to the first compliance move, in 2009, because we will estimate the impact of raising teacher's wage on the students' performance using *Prova Brasil* of 2011.[25]

Until recently public school systems did not require a university degree as part of the qualifications to become a primary teacher, they used to demand just that the candidate has a vocational diploma in teaching. It was just since 2008 that a university degree is required of teacher candidates. Therefore, in almost all municipal school systems there are primary teachers with and without a university degree and some municipalities have different pay structures to each kind of teacher, with and without university diploma, operating like two sub-careers. Usually teachers with college diploma earn higher salaries.

Public school system's pay policy is based on salary formulae that reward teacher characteristics such as possessing graduate degrees and master or post-graduation certificates, and, mainly, seniority. Despite its increasing adoption among developed countries, performance-based pay is almost nonexistent amongst municipal school systems in Brazil. Only 2.3%, or 22 municipalities, among 955 who answered this survey question, adopt a system of pay based on performance[26]. Typically, teacher salary consists of two parts: (*i*) a base salary, established accordingly to the teacher's workload; and (*ii*) an additional part based on teacher's seniority and number of hours of graduate credits or

[23] According to the law, the minimum teacher salary is adjusted yearly at the projected increase of *FUNDEB* resources.

[24] Direct Action of Unconstitutionality No. 4,167, of October 2008.

[25] After the results of the Prova Brasil 2013 that will, probably, be released on October 2014, we intend to analyze that second move and we will estimate again the impact of the salary hike using 2013 data. However, since the decision of the Supreme Court becomes unappealable only on 14th April of 2014, perhaps public officials had not felt themselves obliged to comply with the law beforehand.

[26] The state with more municipalities which has this kind of performance-based pay scheme is the state of Ceará, with 5 municipalities, among 39 respondents (12.8%). In addition to these municipalities of Ceará, other 7 municipalities in the state of São Paulo (out of 184 respondents), 2 in Santa Catarina (81 respondents), 2 in Piauí (49 respondents), and one in each of the states of Espírito Santo, Mato Grosso do Sul, Minas Gerais, Paraná, Rio Grande do Norte and Rondônia have performance-based pay. Only 7 of those 22 municipalities have adopted such a scheme of compensation between the two editions of *Prova Brasil* used in this study. This extremely low number makes us confident in rejecting any influence of these schemes on the obtained results.

graduate degrees teacher has. Generally these rewards are calculated as a percentage of the base salary[27]. Thus, if the education and experience of the average teacher in a school system did not change from one year to the next, then average teacher pay would increase by the same percentage as well. When school systems raise the pay of teachers, they normally increase all the cells of these schedules by a fixed percentage.

According to the new law, every school system that were paying teachers a base salary of less than R$ 950 per 40 hours of work per week, or proportionally equivalent, must raise the salary on January 2009 by at least 2/3 of the difference to the established minimum value. The transition to new minimum base salary value should have been completed by January 2010, when the school systems must pay at least the minimum salary as a base salary to their teachers, which was R$ 1,024.67 at the time. Thus we applied those rules to detecting which municipalities comply with the law and to classify them into treatment and comparison groups as will be presented in Methodology. Before presenting data, it should be clarify that national minimum salary is annually updated based on the nationally variation of the resources from *FUNDEB* per pupil.

3 Data

The dataset were obtained through the combination of information about teacher salaries and municipal teacher career structures, provided by our survey; two educational database, *Prova Brasil* and Brazilian Census of Basic Education, both administered by *INEP*; and data from other Brazilian agencies: (*i*) basic education fund resources (*FUNDEB*) available for each municipality and the amount used with teachers payroll, obtained from *Fundo Nacional de Desenvolvimento da Educação* (*FNDE*), an agency under the Ministry of Education; (*ii*) municipal socioeconomic indicators and institutional characteristics of the education sector from each municipality held by *IBGE*; (*iii*) information about the existence of municipality public retirement and pension system[28] provided by the Ministry of Social

[27] Usually there is no discretion to award teacher's previous relevant experience. When hired a teacher receives a beginning salary which value depends on her/his diplomas, never on her/his other previous experiences.

[28] The Special Social Welfare Policy (RPPS – *Regime Próprio de Previdência Social*), of contributive character, is the policy which guarantees a different scheme for retirement and pension payments to public servants in an effective position in the Union, the States, the Federal District and almost 2000 Municipalities, of a total of 5,564 Brazilian municipalities. The remaining municipalities maintain their public servants connected to the General Social Welfare Policy (RGPS). The Special Policy has to observe the principles of financial and actuarial balance and is subject to the orientation, supervision, control and audit by the Ministry. We highlight three of the distinguished features between these policies: (*i*) in RPPS the retirement payments are equal to the last salary received and in RGPS are based on an average of the 80% higher salaries received; (*ii*) in RPPS the retirement benefits are readjusted according to salary growth (parity), and, in the other hand, RGPS has as readjustment rule the general inflation rate; and (*iii*) there is no cap of benefits and contributions in the RPPS, in contrast to RGPS which is characterized by caps on benefits and contributions (Brasil, 2009). Therefore we should expect harder times to public officials after the introduction of the national teacher's minimum salary in municipalities with RPPS and whose teacher base salaries were below the national minimum salary.

Security; and (*iv*) electoral and political information obtained from Brazilian Electoral Superior Court.

3.1 Survey with municipal departments of education

In Brazil, except for the *Relação Anual de Informações Sociais* (*RAIS*)[29], there is no comprehensive source of information about municipal teacher salary, and there is absolutely no information about their beginning (base) salary. In order to determine whether municipal school systems comply with the national minimum teacher salary we need a precise source of its teacher base salary. But the existed information about salary in the RAIS is the final remuneration, including some benefits and rewards for seniority, for instance.

Thus, to circumvent limitations of existing databases, we carried out a survey with municipal departments of education in partnership with the *National Union of Municipal Secretaries of Education* (*UNDIME*[30]), to get precise information about teachers' salaries and career structures. A copy of the questionnaire used in the survey is available on request from the authors.[31]

Municipal school systems covered by our survey informed salaries paid on January of each year from 2008 to 2013. Based on minimum base salary value of each municipal school system we classified units as target or non-target population. The target population is municipal school systems whose minimum base salary was below the national minimum salary.

As described earlier, public primary teacher careers often are divided in two kinds of sub-careers, one for college graduated teachers and other for non-graduated ones. Both sub-careers usually are composed by different workloads contracts[32]. In order to get the average teacher salary of each municipal school system we first average different workload base salary out for each sub-career assuming the same proportion of teachers in each

[29] *RAIS* is an annual, matched employer-employee, administrative data set collected by the Brazilian Ministry of Labor. It is a panel of workers and firms, containing the universe of formal firms and workers.

[30] Acronym in Portuguese for *União Nacional dos Dirigentes Municipais de Educação*, which is a non-profit organization supported by contributions of its members, almost 5,000 municipal departments of Education. The president and directive board of *UNDIME* are elected by its members. Its mission is to coordinate, mobilize and integrate the municipal secretaries of education to improve public education. Through *UNDIME*, the municipal departments of education may exchange information and experiences with each other. It organizes and promotes research, meetings, seminars and forums and, in addition, maintains contacts with unions, non-governmental organizations, social movements, and other entities of the civil society. Also establishes relationships with the three branches of government: Judicial, Legislative and the Executive of other government levels, aiming to contribute to the formulation, promotion and monitoring of education policies.

[31] *UNDIME* often carries out quick surveys about education issues and sometimes carries out broader surveys like ours. When asked to answer the questionnaire, the members of the municipal departments of Education were told that their identity and their municipality identity would not be disclosure and all the information would be displayed through averages or by group of municipalities. Furthermore, no information would be passed on to third parties. Therefore, because respondents were answering to their own peers, we believe that the survey brings us accurate information. Even though, we intend to give our data some consistency checks using other databases.

[32] Obviously we always use salaries values after converting them into 40 hours per week.

workload[33]. Then, we calculated the average teacher salary for each municipality from the weighted mean teacher salary, using the proportion of teachers with and without college degree collected in Brazilian Census of Basic Education as weight.

For the purpose of characterizing treatment status, in municipal school systems with both types of sub-careers, it was considered as target units those school systems that have at least one type of teacher contract whose salary was below the national minimum salary. In this version of the article we work only with base salaries. We argue that this is a fair procedure because, ceteris paribus, all the schedule of teacher salary normally increases in the same proportion of their base salary[34].

3.2 Pupils' tests scores, school system variables and socioeconomic characteristics

There are basically two ways of utilizing measures provided by standardized tests. First, calculating the value added of a pupil in a given period of time and school grade, which requires the existence of a panel of testing scores of the same individuals over time. In this case, it is possible to construct measures of value added for each teacher. Second, in the absence of individual panel, one can analyze the evolution over time of the same grades. In this case it is necessary to rely on stronger hypothesis. In Brazil there are few experiences of large-scale standardized tests structured as a panel of individuals along their school years, so often the latter approach is used.

Due to the absence of a national standardized test that follows individuals along the schooling years, it is impossible to assess the impact of the increase of teacher salary on pupils' performance using models of aggregated value. We use test scores in Mathematics and Portuguese of 5th grade pupils obtained in *Prova Brasil*, a nationwide standardized test taken by almost all public school students of 5th and 9th grades every two years on November.

In the analysis we used the results of *Prova Brasil* 5th graders in its 2007 edition, the last before the establishment of the national minimum wage of the teacher, and 2011 edition, the last available version of this nationwide proficiency test. We also obtain information on pupils and teachers characteristics from *Prova Brasil* socioeconomic questionnaires, responded by 5th graders and by their Math and Portuguese teachers. From these teachers questionnaire we get information about whether they combine teaching with other paid jobs before and after salary hikes.

[33] Unfortunately we do not have the relative proportions of each workload. However differences in salary per hour among different workloads are quite small. Thus the imprecision eventually introduced is arguably very small.

[34] We will test the robustness of the results with other teacher salary measures in a next version of the paper.

As we do not have the salary of each teacher whose pupils took the *Prova Brasil* exam, just the average salary, we had to work with municipalities pupils average score in 2007 and 2011 editions. It is important to clarify that part of the Brazilian municipalities had not their average score calculated and publicized. Actually 5,136 municipalities had their 5th grade pupils mean scores in *Prova Brasil* 2011 publicized out of 5,564 municipalities. In 2007, the quantity was a little smaller, just 4,986 municipalities. The mean score of the rest of municipalities were not calculated because *INEP* do not calculate them when less than 20 pupils and/or less than 50% of the enrollees of a school system had taken the test. Considering municipalities that informed their salaries and had their mean pupils score in *Prova Brasil* of 2007 and 2011 calculated by *INEP*, our sample reduces to 817 municipalities. And after considering other covariates such as pupils' socioeconomic characteristics and teachers and municipal school system characteristics, the sample reduces to 711 municipalities.

Schools infrastructure characteristics are available in Brazilian Census of Basic Education and we constructed the municipal variables from the average characteristics among its municipal schools.

3.3 Socioeconomic and institutional characteristics of municipalities

Socioeconomic and institutional characteristics of municipalities, such as population, per capita GDP, illiteracy rate and the existence of Municipal Council for Social Monitoring and Control of resources from *FUNDEB* were obtained from the *Instituto Brasileiro de Geografia e Estatística* (*IBGE*). In addition, the source of the information of the mayor's political party affiliation is the *Tribunal Superior Eleitoral* (TSE)[35].

3.4 Teachers test scores

We use a unique dataset built merging two well-known databases administered by *INEP*, data from *Prova Brasil* and from *ENADE*[36], a yearly College exam taken by first year and senior students. We merged the last version of *Prova Brasil* (2011) database with the database of *ENADE* 2005 and 2008. We choose these two ENADE data sets because on those years courses related to teaching profession were assessed[37]. We considered that the

[35] Brazilian Electoral Superior Court.

[36] The acronym *ENADE* stands for *Exame Nacional de Desempenho dos Estudantes* in Portuguese (National Survey of Students Performance). Courses are split in three different groups which have their students performance assessed every three years.

[37] In 2005, took the exam students of Architecture and Urbanism, Biology, Social Sciences, Computer Science, Engineering (in eight different fields), Philosophy, Physics, Geography, History, Languages, Mathematics, Pedagogy and Chemistry. In 2008, took the exam students of the same courses and of some recently opened shorter term courses of technologists.

chance of finding teachers among 2005 and 2008 *ENADE* participants were considerably higher.

Teachers whose students took *Prova Brasil* in 2011 were identified in 2005 and 2008 *ENADE* database. Therefore we could connect teachers' test scores in *ENADE* with their students' test scores in *Prova Brasil*. Furthermore we merged this resulting data with our data of teacher salaries. Then we can associate a proxy for teacher quality (*ENADE* scores), with a proxy of teacher effectiveness (students test scores), and, finally, with teacher salaries and the municipal school system treatment status.

4 Descriptive Statistics

In this version of the paper we focus on primary school, we present statistics and results just for the 5th grade[38]. In our survey with all municipal departments of education, 1,600 of them entered the questionnaire web system and answered at least one question and 1,111 reached the end of the questionnaire. However not all municipalities filled valid information for salaries of their primary teachers at least in the period between 2008 and 2011.[39]

After summing up all municipalities that sent us their primary teacher salaries along the period from 2008 to 2011, we got 907 units of analysis[40]. Unfortunately not all of those 907 municipal school systems whose teacher salaries were informed by municipal department of education have statistics about pupils' test scores and *Prova Brasil* questionnaires. Part of the Brazilian municipalities had not their pupils' average score in *Prova Brasil* been calculated and publicized. Actually 5,136 municipalities had their 5th grade pupils mean scores in *Prova Brasil* 2011 publicized out of 5,564 municipalities. In 2007, the quantity was a little bit smaller, just 4,986 municipalities. The mean score of the rest of municipalities were not calculated because *INEP* do not calculate them when less than 20 pupils and/or less than 50% of the enrollees of a school system had taken the test. When we consider other variables such as information about pupils' socioeconomic characteristics, teacher and schools characteristics and other information about the municipal school

[38] In a next version we intend to include analysis for lower secondary school (9th grade).

[39] Of 1,441 municipalities contained in our representative stratified sample from the population of approximately 5,000 municipalities contained in Undime's contacts database, 885 registered on the questionnaire survey system, what represents 61.4% of the sampled municipalities, and answered at least one question. However, only 578 municipalities concluded the questionnaire, what covers 40.1% of the representative sample. Other 285 municipalities out of the representative sample concluded the questionnaire and gathered this paper database. Weights were calculated in order to recover national representativeness of the database.

[40] Of those 907 municipal primary school systems, 511 were paying less than the stipulated minimum base salary in 2008 (56.9%). But considering the average base salary, calculated using the school system proportions of teachers with and without college degree, 41.6% of the respondents had the average base salary smaller than R$950 in 2008. In 2011, the percentage of municipal school systems which were paying less than the legal minimum as a base salary fell 23.5 p.p., to 33.4% (300 municipalities). In 2013 the proportion of non-compliers fell a little bit more, to 295 municipalities, 32.9% of our respondents.

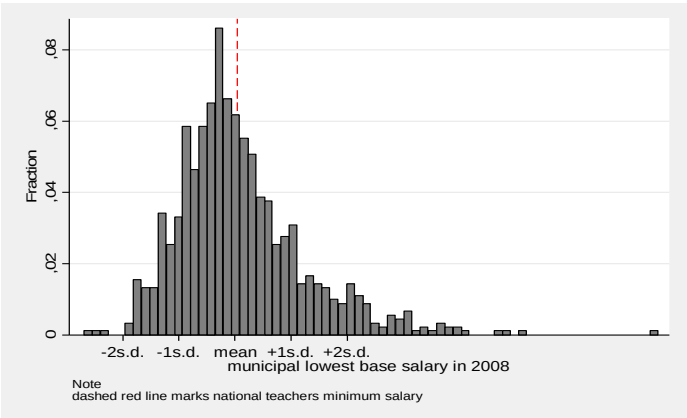
system, the sample reduces to 711 municipalities. After receiving all the questionnaires we calculate weights for each stratum to recover the characteristics of the population of Brazilian municipalities[41]. Table A.1 in the Appendix presents estimates for characteristics of the population of Brazilian municipalities obtained from the weighted sample and tests of its adherence to real population characteristics.

Table A.1 in the Appendix presents a comparison of our weighted sample and the whole population of municipalities in respect to some of their socioeconomic characteristics, their school system budget, their school infrastructure and pupils' family socioeconomic background. In Table A.1 we can see an almost identical distribution of municipalities through Brazilian Regions between sample and the entire population of municipalities after applying sample weights. In terms of municipal characteristics, they are quite similar between our sample and the population, but adult illiteracy rate (Panel A). Besides, the only difference in terms of school system characteristics is the proportion of municipal budget spent on education. The weighted sample reveals a proportion of municipal budget spent on education a bit smaller. Municipal school facilities are similar between our weighted sample and the population of Brazilian municipal school systems. And there are statistically significant differences between our sample and the population only in part of the socioeconomic background variables (Panel B). Although our weighted sample slightly overestimates population socioeconomic status in some dimensions, we argue those differences are relatively small and do not taint the representation of the population. Finally, Panel C brings the same kind of comparison relatively to some variables of interest. Perhaps reflecting the high level of socioeconomic status of their pupils' family, the estimates for test scores obtained through the weighted sample are higher than the national mean. However the differences between the sample and the population test scores variation almost disappear. They are null in the period 2005-2007 for both disciplines and the estimates are about 1 point higher than the national test score variation in both disciplines, statistically significant at 10% level in Math and 5% in Portuguese, but they have very low economic significance.

[41] In Pinto, Silva Filho e Vieira (forthcoming), whose objectives are: (*i*) to describe and show the consistency of the whole survey; (*ii*) to find correlations between inter municipal school systems teacher salaries variability and the characteristics of municipalities and their school systems; (*iii*) and to establish the correlation between the compliance with the national minimum salary and the characteristics of municipalities, their school systems and the characteristics of the municipal department of education head, we show the adherence of our weighted whole sample to the entire population of Brazilian municipal school systems in terms of characteristics. Before applying sample weights, there are significant differences between our sample of 907 municipal school systems and the whole country in most of the variables of interest and covariates. Sample weights strongly enhance the representativeness of the sample, approximating the sample characteristics to the characteristics of the population of municipalities. Thus we argue that our weighted sample represents well Brazilian municipal school system. The trimmed sample used in the present article is worse in representing the population characteristics in levels but quite good in representing it in the first difference. Since our impact estimates rely on difference-in-differences methods, we argue in favor of external validity of our results.

The majority of Brazilian municipal school system was impinged by the introduction of the national minimum salary[42]. Figure 1a shows the histogram of the lowest value of each municipal school system base salary of beginning teachers in January 2008[43]. Every school system which has at least one type of teacher contract stipulating a base salary below the national minimum is classified as impinged ones (target units). On the other hand, school systems whose base salaries, in their totality, were above the national minimum salary are not impinged (not target units) by the law[44]. The traced red line marks the value of the stipulated minimum to be observed nationwide in January 2009. We see that the defined minimum salary was almost the national average considering the municipalities which informed us their teacher salaries. Figure 1b presents the histogram of municipal average teacher base salaries in January 2008.

Figure 1a Histogram of lowest Municipal base salary of beginning teachers

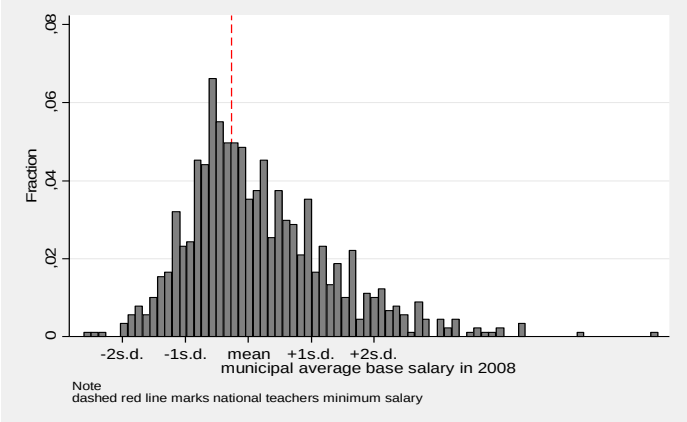


[42] After applying sample weights, we find that actually 61.2% of the Brazilian municipal school systems had the average base salary smaller than R$950 in 2008, and consequently were impinged by the law introduction. In 2011, the percentage of municipal school systems which were paying less than the legal minimum as a base salary fell 26.8 p.p., to 34.4% of Brazilian municipalities. Even though there was a big reduction in the proportion of municipalities with minimum salaries above the national minimum, it is still a high rate of non-compliance to the law. In 2013, 32.9% of Brazilian municipalities remain on the margin of the law.

[43] Often the lowest base salary in each municipal school system corresponds to the base salary of the beginning teacher without college degree.

[44] Here we had to assume that base salaries remained constant between January and June of 2008, when the law was enacted or, if it had been raised, the lowest municipal base salary in June would be still below the established national minimum.

Figure 1b Histogram of Municipal base salary of teachers



The histograms show that there is a relatively high dispersion in Brazilian municipal base salary distribution. In another work, we verified that observable characteristics are responsible for half of the variability in the level of teacher beginning base salary amongst municipal school systems, leaving a vast territory for unobserved variables. Moreover, the role of unobserved characteristics grew about 7 p.p. in 2011.[45]

Salaries are higher in the southern part of Brazil[46], where less than half of its municipalities (46.1%) have been impinged by the new minimum teacher salary. Meanwhile, in the northern and mid-western regions 78.3% of its municipalities have been impinged by the law[47].

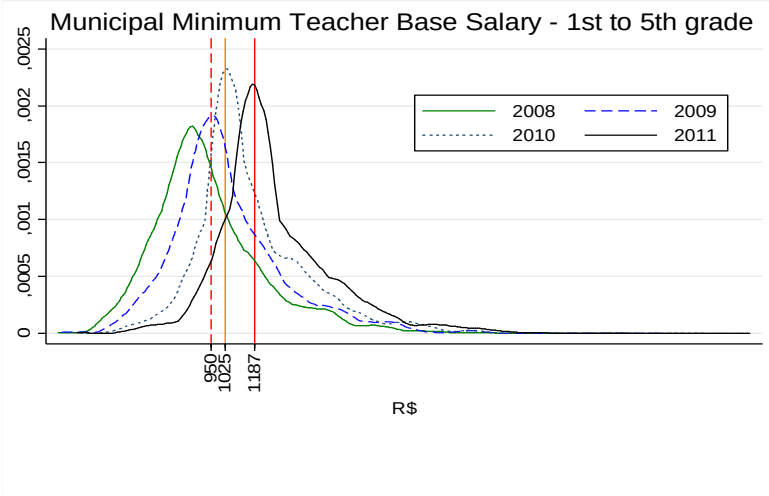
The institution of the minimum salary moved partially municipal teacher's salaries as shown by Figure 2. Looking at the distribution density of municipal lowest teacher base salary in the period from 2008 to 2011, we can see a high proportion of municipalities which disobey the law of teacher minimum salary and, at the same time, an increase in the mass of school systems which paid exactly or nearly around the stipulated minimum from 2009 (dashed red line) to 2010 (orange line) or to 2011 (red line). Considering the mass of municipalities whose teacher's beginning salary is higher than the national minimum salary and that the minimum salary grown more than the GDP between 2008 and 2011, as shown further in Figure 4, we can infer that the institution of the minimum salary contributed for an increase in real terms of local teachers' salaries. Despite this, a significant part of municipalities did not comply with the national teachers' minimum salary, probably due to the absence of disciplinary punishment under the law, the discussion about the constitutionality of the law and the existence of severe budget constraints in some local governments.

[45] Pinto, Silva Filho e Vieira (forthcoming).

[46] South and Southeast Regions.

[47] Table A.2 in the Appendix shows the proportion of impinged and non-impinged municipalities by region and state.

Figure 2



From 2008 to 2009, Brazilian municipalities raised teacher base salaries on average by 12.9% of variation, what represented a considerable gain in real terms for teachers since Brazilian economy witnessed an annual inflation rate of 5.9% that year. Our data reveals that municipal school systems which comply with the law (treated) raised salaries sharper than non impinged ones (included in the broad untreated group, column (B) in Table 1) and never-takers (also included in column (B), but isolated in column (C)). As shown in Table 1, compliers raised salaries 16.2 p.p. (113.84 Brazilian Reais) more than the others and 15.0 p.p. (130.31 Brazilian Reais) more than never-takers. And it is important to mention that we could not reject the null hypothesis that the difference between salary variation of always-takers and of never-takers is zero.

Table 1 Average teacher base salary (R$) and base salary increase (R$) and variation by groups (2008-2009) - treated and untreated

	Treated (A)	All untreated (B)	Never-takers (C)	Diff (A)-(B)	Diff (A)-(C)
# obs	180	525	211		
2008 average salary	883,79	1.120,67	820,76	-236,88 ***	63,03 ***
st-dev	149,44	372,85	201,04	19,72	17,77
2009 average salary	1.080,55	1.203,59	887,20	-123,04 ***	193,35 ***
st-dev	173,82	392,12	199,06	21,46	18,86
Salary increase	196,7558	82,91	66,44	113,84 ***	130,31 ***
st-dev	152,1673	86,31	75,29	11,95	12,47
Salary variation	24,4%	8,2%	9,4%	16,2 ***	15,0 ***
st-dev	22,7%	10,4%	13,4%	1,8	1,9

Notes:

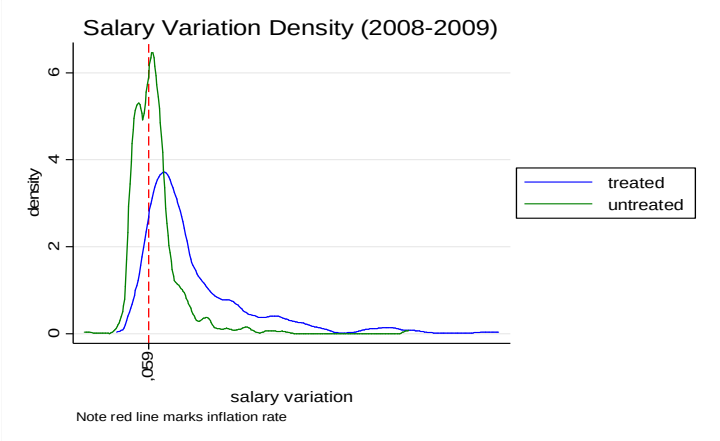
(1) Differences in salary variation expressed in p.p.

(2) Salary increase of Broad untreated is higher than of Never-takers at 5% of statistical significance, but their salary variation are not statistically different.

Figure 3 brings a comparison between salary variation densities of treated and untreated municipal school systems. While salary variation of untreated is highly

concentrated around the inflation rate, salary variation of treated school systems is more disperse and its mean and median are significantly above the inflation rate.

Figure 3



Now we expand the period of analysis to the year of 2011. Even though a comparison made between municipalities which were burdened by the law enactment, i.e. those whose salaries were below the minimum wage (solid bars in Figure 4a) in 2008, and municipalities not burdened, i.e. those whose salaries were above the minimum in 2008 (transparent with blue line bars), shows that the burdened ones raised their salaries in a more pronounced way than those not directly burdened[48]. Municipalities whose teachers' salaries were below the national minimum salary when the law was enacted experienced larger teachers' salary hikes than the others between 2008 and 2011, 59.1% against 28.7%. Figure 4a shows higher fractions of impinged municipalities characterized by larger rates of salary increase than those that were not impinged. In Figure 4b we see higher fractions of compliers municipalities (treated) with larger salary increase rates than untreated municipal school systems. The same pattern arises when analyzing the variation observed from 2008 to 2009, but obviously at a smaller dimension (see Figure 5).

[48] We say directly not burdened because it could be the case that some municipalities has been burdened indirectly, for instance, by effects in the local labor market caused by the imposition of the national minimum salary.

Figure 4a

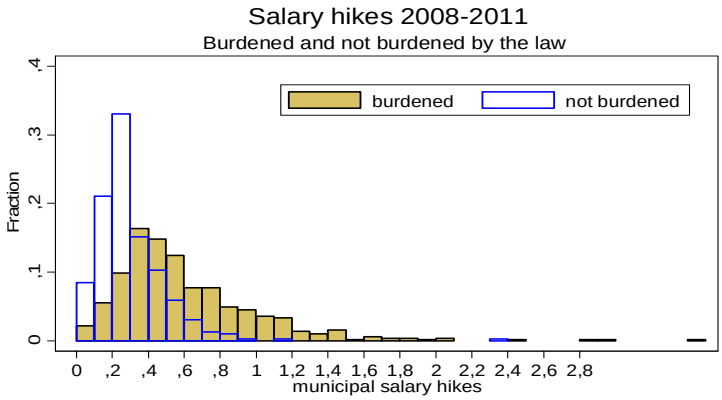
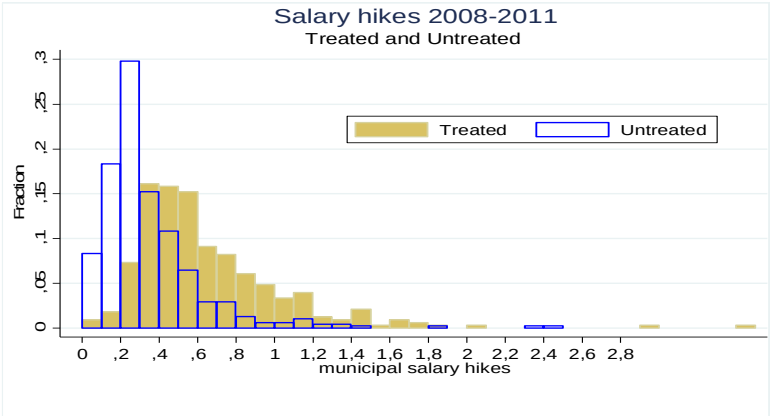


Figure 4b



Using the trimmed sample and comparing just municipalities burdened by the law which complied with the minimum teacher salary at least one school year versus municipalities that did not receive treatment at all, we see that compliers raised their teacher salaries on average by 63% (or 502 Brazilian Reais) in the period against 33.5% (or 359 Brazilian Reais) by the other group[49].

The average municipal teacher base salary in Brazil between 2008 and 2011 increased 46.8%, an extraordinary growth in real terms since the accumulated inflation rate reached 17% in the period. Moreover, teacher salaries increased more than the Brazilian GDP which has grown 41.7% in the same period. It is important to note that, as shown in Figure 6, municipal school systems which complied with the law at least during one school year in the period between 2009 and 2011 were mainly the responsible for the observed salary hike.

[49] Even after increasing more their teacher salaries, treated municipal school systems, on average, pay less to their teachers (beginning base salary of R$ 1.364,07) than the others municipal school systems (beginning base salary of R$ 1.564,50).

Figure 5

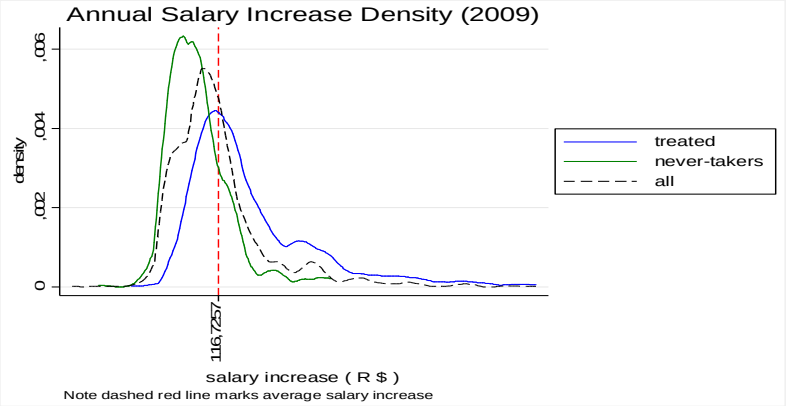


Figure 6

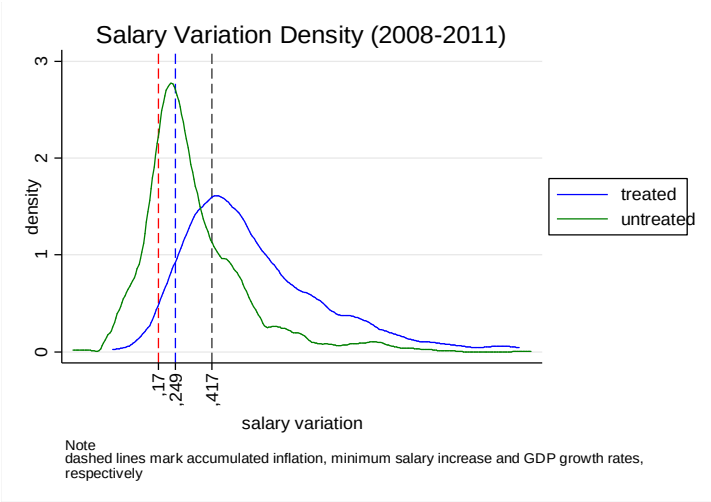


Table 2 shows the distribution of compliers, which will be used as treated, through Brazilian regions and compares it with distribution of units that could be used as a comparison group, all untreated and just never-takers. The statistics were obtained after taking in consideration our complex sample design. It is interesting to note that municipal school systems which refused to comply with the law (never-takers) are relatively more spread across Brazilian territory. Every region, including the richest South and Southeast has more than 14% of its municipalities as never-takers. The North, which has the highest proportion of never-takers among its municipalities, has 24.1% of its municipalities as never-takers. The participation of every region is well balanced in this category, considering its representativeness in the whole country. On the other hand, Northeast municipalities are weakly represented amongst all untreated. However, conditioned by regional localization, only the proportion of municipalities with active Education Council remain statistically different between treated and never-takers.

Table 2

t-tests of equivalence of means between treated and untreated and between treated and never-takers at baseline

	Treated (A)	Untreated (B)	Diff (A) - (B)	p-value		Never-takers (C)	Diff (A) - (C)	p-value	
Municipal characteristics									
Population (2007)	25.658	40.612	-14.953	0,03	**	21.494	4.165	0,23	
Per capita GDP	6.198	10.576	-4.378	0,00	***	8.273	-2.075	0,00	***
Adult illiteracy rate (%)	19,8	13,5	6,28	0,00	***	16,6	3,14	0,01	**
Region N	0,078	0,075	0,003	0,94		0,080	-0,002	0,95	
Region NE	0,558	0,234	0,324	0,00	***	0,362	0,196	0,00	***
Region SE	0,192	0,346	-0,153	0,00	***	0,240	-0,048	0,42	
Region S	0,112	0,257	-0,144	0,00	***	0,209	-0,096	0,06	*
Region MW	0,059	0,088	-0,029	0,08	*	0,110	-0,051	0,02	**
Active Munic Educ Council	0,623	0,773	-0,150	0,00	***	0,746	-0,123	0,04	**
School Council	0,755	0,789	-0,034	0,49		0,815	-0,060	0,29	
Fundeb Council	0,911	0,944	-0,033	0,36		0,929	-0,017	0,67	
Pro-mayor representatives	0,591	0,568	0,023	0,24		0,573	0,018	0,47	
2009 Mayor's reelection	0,230	0,321	-0,092	0,09	*	0,236	-0,007	0,91	

Table A.3 in the Appendix presents summary statistics and t-tests for the equivalence of the means of treated and comparison groups relatively some characteristics of school system, school infrastructure and pupils' characteristics according to the estimates obtained from the sample of 711 respondents which have information about all covariates included in the model we use to assess the impact of teacher salary on pupils proficiency.[50]

Treated municipalities are less populated, poorer, have greater illiteracy rates and receive fewer resources from *FUNDEB*[51] than untreated municipalities. Furthermore, as shown in the Table, these two groups of municipal school systems are different in most aspects. Furthermore, school infrastructure is poorer amongst treated, considering some of the informed facilities, and their pupils come from more deprived background. Thus, to avoid bias when estimating the impact of teacher salary hikes on pupils' performance, the construction of the comparison group would require the adoption of a selection on observables method.

Generally, treated units are less clearly distinct from never-takers units considering covariates. When we test the equivalence of treated and never-takers conditional means, after controlling for the region where municipality is located, we could reject the null

[50] The weights used to recover the population characteristics from the sample were recalculated. We tested whether estimates obtained from the trimmed sample are statistically different from the population characteristics as we did with the whole sample. The adherence of weighted trimmed sample to the population is worse than when the whole sample is used, but we could not reject, at 10% level of confidence, the null hypothesis of equivalence of the estimates and the population mean for most of the characteristics.

[51] They receive fewer resources from *FUNDEB* because they tend to be located in poorer states which collect lesser amounts of taxes and contributions. On average, impinged municipalities spent in 2008 a larger proportion of municipal budget in education (29.7% against 27.6%, statistically significant at 1% level), probably because they are poorer and consequently have smaller budget revenues and receive lesser resources from *FUNDEB*. Actually, our data showed a strong negative correlation between municipal per capita GDP and the proportion of municipal budget spent in education.

hypothesis of equivalence of groups means with 10% of statistical significance just for teachers characteristics, such as age and experience, the proportion of school with insufficient quantity of teachers, and the proportion of schools without electricity and that do not provide meals. Despite this, even for the non-compliers we will rely on selection on observables method. It is important to notice that, as shown in Table 1, the salary in 2008 of treated units, on average, was higher than of non-compliers, a fundamental distinction that we intend to attenuate with selection on observables.

Table 4 Comparison between groups of variables for the investigation of transmission channels at the baseline

	Treated (A)	Untreated (B)	Diff (A) - (B)	p-value	Never-takers (C)	Diff (A) - (C)	p-value
Insufficient teachers in schools (2007)	0,025	0,043	-0,018	0,02 **	0,050	-0,024	0,03 **
Teacher absenteism (2007)	0,015	0,029	-0,013	0,04 **	0,031	-0,016	0,12
Ful-time teachers (2007)	0,638	0,589	0,049	0,14	0,625	0,012	0,75
Port teachers who correct hw (2007)	0,834	0,840	-0,005	0,72	0,847	-0,012	0,46
Math teachers who correct hw (2007)	0,829	0,840	-0,011	0,29	0,835	-0,007	0,59

About the variables we use to investigate transmission channels at the baseline, the proportion of full-time teachers, and the proportions of teachers that, according to their pupils' report, always or almost always correct home-works in treated units are not statistically different from the proportions observed among untreated units. The proportion of schools which suffer from insufficiency of teachers is smaller among treated units than among untreated and never-takers, in particular. Besides, the proportion of schools which suffer from teacher absenteeism is smaller among treated units than among all untreated units. All differences were obtained at 5% of statistical significance level.

Although we find statistical differences on the propensity to the treatment depending on mayor's political party affiliation, maybe surprisingly, after controlling for states where municipalities are situated, mayors' political party affiliation revealed no significant correlation to compliance with the law[52].

5 Methodology

When comparing the differences in average outcomes (e.g. pupils' performance) of treated and untreated school systems, it is difficult to disentangle the impact of the salary hike from the effect of other kind of policy. A simple estimator based on the difference in

[52] In the sample there are 23 different political parties, some with a very small number of affiliated mayors. We need aggregate those parties somehow. We intend to test for measures of party ideological spectrum in next version.

means between treated and untreated groups would be tainted. The salary of teachers should be endogenous with respect to other policies of the school system and to pupils' learning and decided simultaneously with other policies. In order to deal with the problems associated with endogeneity and simultaneity, the identification of an exogenous source of variation in teacher salaries is required to identify a causal relation. We explore the introduction of the national minimum teacher salary, by federal law, as exogenous variation in teacher's pay.

In the present context, as the introduction of the minimum teacher salary was decided at the federal level and municipal leaders largely did not participate in the decision process, we argue that the salary hikes induced by the minimum salary introduction work as an exogenous source of salary variation. Thus it is possible to exploit this fact to identify the effect of teacher pay on pupils' performance.

However, as shown in the previous section, due to institutional characteristics of Brazilian school systems and the absence of explicit penalties for disobeying the minimum salary imposition or the existence of judicial appeals against the law, the assignment to treatment is not deterministic. Ultimately, to observe the law is a decision of the local administrators. Thus, not all municipal school system assigned to treatment underwent it. In other words, once assigned to treatment, municipalities self-select themselves to the treatment.

Such a decision can be greatly influenced by observable and unobservable characteristics of the municipality and its school system. Considering what Brazilian Constitution determines, municipal teachers' salaries should be explained by municipal revenues; transfers received from *FUNDEB*, which are based on the number of enrollees in each municipal school system; and the number of teachers employed by the school system. On the other hand, salaries can also be explained by numerous other observed characteristics and even ones that are unobservable by the analyst, as the relative importance given to education by the current ruler of the municipality, or even by his/her predecessors, and the influence and bargaining power of local teachers' unions, just to mention two examples. The important role played by unobserved and unobservable variables in explaining salary differences and treatment status give us support in applying Difference-in-Differences (DID) methods in the estimation of the impacts of salary raises on pupils' performance.

DID method allows one to control for fixed effects of school system and municipalities, helping in circumventing bias associated with unobservable variables. Furthermore, to reduce self-selection bias we rely also on a selection on observables method. The use of an estimated propensity score helps in limiting bias associated to observed characteristics that are correlated to the treatment and to the potential outcome of

interest at the same time. According to DuGoff et al (2014), more than just essential for addressing confounding in observational studies, only Propensity score methods combined with survey weights may lead to results generalizable to the survey target population when we have complex sample design. Not incorporating the survey weights would compromises external validity, such that outcomes would not be generalized to national figure. That paper clarifies the appropriate inferences for different propensity score methods and suggests guidelines for selecting an appropriate propensity score method based on a researcher's goal. Aiming to obtain consistent estimates, after estimating the propensity score using a kernel method[53], we calculate the ATT weights, according to Abadie (2005).

We follow the recommendation of DuGoff et al (2014) and include the survey weight as a predictor in the probit model chosen for propensity score estimation. As put by the authors, the survey weight may capture relevant factors, and perhaps variables related to the units probability of responding to the survey and to undergo treatment. Furthermore, we agree that the propensity score model does not need to be survey-weighted, as we are not interested in generalizing the propensity score model to the population. However, in the outcome model we need to incorporate survey weights as we aim to estimate Population Average Treatment Effect on the Treated (PATT). The propensity score weights and survey weights are multiplied to form a new weight for the outcome regression. In that way, incorporating the complex survey, we estimate the effect of increasing teacher salary on the entire treated population.

In our analysis we consider, as post-treatment results, pupils' test scores in *Prova Brasil* of 2009, taken in the end of the first school year after the introduction of the national minimum salary, and, in a second exercise, test scores in *Prova Brasil* 2011, the last version available of this nationwide proficiency exam which is taken every two years. As baseline, we always use tests scores in 2007 edition. We estimate ATT for the first year of the policy and afterwards we estimate ATT for a larger time extension of the policy.

In the first exercise, was considered as treated municipal school systems that were paying their teachers a base salary below the stipulated national minimum in 2008 and raised base salary in 2009 according to the law. We compare treated units with two different untreated municipal school systems: a broad group consisted of all other municipal school systems, and a restricted group formed by just non-compliers, school systems whose teacher salaries were below the national minimum in 2008, but did not raise them in response to the law.

The potential outcomes are determined by a set of covariates in addition to the treatment as in the following model:

[53] Alternatively we use nearest-neighbor matching as a robustness check.

$$Y_{it} = \alpha + \beta\, d_i + \delta\, \mathbb{I}\{t = 2011\} + \gamma \mathbb{I}\{t = 2011\} \cdot d_i + \rho' X_{it} + \varepsilon_{it}$$

where the dependent variable, Y_{it}, the 5th graders average test score of the municipal school system i in year t in Math or Portuguese is explained by a constant (α); the treatment group fixed effect captured by the coefficient of an indicator variable which assumes value 1 if the municipal school system were treated and 0 otherwise, d_i; the common effect of the passage of time, represented by δ; the parameter of interest, γ, representing the impact of the treatment, the abnormal teacher salary hike, on the dependent variable; and a vector of covariates X that helps to explain the dependent variable. The model becomes complete with ε_i, the error term.

The key identifying assumption is that γ would be zero in the absence of treatment after matching on the propensity score ($E[\varepsilon_{it} | \mathbb{I}\{t = 1\} \cdot d_{it}, p_i] = 0$).

We get OLS estimates for the constant term, α, corresponding to the average performance of the comparison group at baseline; for β, representing time invariant differences between treatment and comparison groups; for δ, summarizing the way both groups are influenced by time; for γ, the average treatment effect (parameter of interest); and for ρ', the parameter vector associated with changes in covariates.

Table 5 Pupils test scores of treated and untreated groups

	Treated	Untreated	Diff	p-value		non-compliers	Diff	p-value	
	(A)	(B)	(A) - (B)			(C)	(A) - (C)		
Math test score - 2005	172,1	181,8	-9,645	0,00	***	176,1	-3,979	0,07	*
Math test score - 2007	181,7	193,1	-11,352	0,00	***	187,0	-5,272	0,03	**
Math test score variation (2005-2007)	10,3	11,3	-0,956	0,54		11,2	-0,904	0,62	
Math test score - 2009	194,9	207,0	-12,147	0,00	***	200,6	-5,687	0,11	
Port test score - 2005	162,7	172,4	-9,699	0,00	***	166,4	-3,770	0,06	*
Port test score - 2007	163,5	173,3	-9,815	0,00	***	167,2	-3,729	0,07	*
Port test score variation (2005-2007)	1,3	0,8	0,5	0,74		1,1	0,2	0,90	
Port test score - 2009	174,3	184,0	-9,682	0,00	***	178,8	-4,440	0,11	

For the consistency of the DID estimator, it is necessary to satisfy two conditions: (*i*) if there was no treatment, treated and untreated (or comparison) groups would evolve in the same way considering the potential result; and (*ii*) unobservable characteristics remain constant over time within groups or change across time in the same magnitude in both groups. The first requirement is not testable, but it can be argued favorably if the evolution of the dependent variable was shown similar across groups prior to treatment. As shown in Table 5, there is no significant difference in scores tendency between groups, both Math and

Portuguese test scores variation in the previous period of time (2005 to 2007) are not statistically different between groups.

Our second exercise is to investigate if there is any impact of the salary hike on the proficiency pupils of the 5th grade after three school years. Two key features of the institutional background are important to take in consideration. First, the national minimum teacher base salary varies annually, as explained in the section on institutional framework. Second, municipal school systems showed different behavior in terms of compliance with the law. Part of the municipalities affected by the introduction of the minimum wage fulfilled the legal determination since the first year of the policy, others began to comply with the law in 2010 and yet another group complied with the law only in 2011. Additionally, part of the municipalities has moved their salaries toward the fulfillment of the legislation in a given year and failed to fulfill it in the following year or later. They do not stay consistently at compliance status once they have moved towards the minimum salary. However, on average, the growth rate of the base salary of teachers between 2008 and 2011 inter groups of compliers was almost similar with the exception of municipal school systems which complied with the law only in 2009 or only in 2009 and 2010. Therefore, for the second exercise, we construct two different groups of treated units, a broad one, with all the compliers, indistinguishably, and another restricted treated group, without those two subgroups.

It is important to clarify that doing this we recover the ATT for an average time of exposition to treatment. In this context, the suggested method has one important limitation. As we did not work with treatment dosage and did not consider different exposure time length to treatment amongst treated units, it is assumed that the effect is homogeneous through different doses of treatment, i.e., different salary variations, and ATT is independent of the time that units have been exposed to the salary increase, what is a strong hypothesis. Thus, the obtained estimate is an average of the various doses of treatment and exposure time length.

Then we estimate different ATT according to the time length since the first move towards the national minimum salary. We estimated marginal treatment effects through the following model:

$$Y_{ist} = \beta_{s=\{0,1,2,3\}}\, d_{si} + \delta \mathbb{I}\{t = 2011\} + \tau_{s=\{1,2,3\}} \mathbb{I}\{t = 2011\} \cdot d_{si} + \rho' X_{ist} + \varepsilon_{ist} \ ,$$

where: s represents the quantity of school years since the first move towards the national minimum (that we call years of exposition), i.e. 0 identifying non-compliers and 1, 2 and 3 (those that move towards the national minimum salary in 2011, 2010 and 2009, respectively); β_s captures fixed effects of group with *s* years of exposition; and τ_s captures ATT for marginal time length exposition to the treatment.

Despite being important, controlling for unobserved characteristics would not be enough to overcome the endogeneity problem. Therefore, additionally to the selection on observables method already described, we adopt an instrumental variable approach to try to overcome this problem. Relying on the variability of the distances between the national minimum teacher base salary and the municipal school system base salary when the minimum salary was instituted, we can construct an instrument for the base salary observed in 2011. The idea is to explore the interaction of municipal salary gap to the minimum salary with the timing of its introduction.

To deal with the endogeneity of teacher salary (D_{it}) we propose an exogenous instrument. The value of the distance between the national minimum salary and each municipal base salary observed in 2008 interacted with time dummy works as an instrument for the base salary paid in 2011, determining the Z variable, correlated with the treatment variable, D, earnings in 2011, and not correlated with the error term, or unobservable component of the model expressed in (1). Thus, we have:
$Z_i = I\{t = 2011\} \cdot (\overline{D} - D_{i,2008})$, where $\overline{D}$ is the national minimum salary stipulated in 2008 for 2009 and $I\{t = 2011\}$ is the indicator variable of year 2011.

We run two different estimation procedures, a two stage least squares estimator (2SLS) with and without fixed effects of municipal school system. Furthermore, we propose two different specifications in each model, one with variables at their levels and another with salaries and tests scores in logs to capture non-linearity. In one specification standard errors were clustered at the municipality level, so that the error term is allowed to have an arbitrary correlation within municipalities over time. The drawback of this procedure is that we could not take into account the complex nature of our sample and were able just to consider sample weights[54].

In the case of assessing teachers' performance in *ENADE* we could not use the same method because we do not have teachers' performance at the baseline. Therefore we do not find a causal relation from higher salaries to smarter teachers. However, as we find a significant positive relation between teachers' performance in *ENADE* and pupils' performance in *Prova Brasil*, it would be arguable that at the baseline school systems with poorer performance on average should have teachers of poorer performance in *ENADE* as well.

Aiming to test for the Brazilian context if the cognitive knowledge of teachers, especially related to the content of the subjects taught, is an important determinant of pupils' outcome in Brazil, we investigate whether the performance in *ENADE* explains the

[54] We estimated this IV-DID model using *Stata* command *xtivreg2*, that is not supported by the package of commands *svy* which take into account complex sample designs.

performance of their pupils in *Prova Brasil* exams. In order to investigate this hypothesis, we estimate the following regression model by Ordinary Least Squares (OLS):

$$pupils\_score = \alpha + \beta \cdot X_{school} + \delta \cdot X_{pupils} + \sigma \cdot X_{teach} + \gamma \cdot teach\_score + \varepsilon$$

where X_{school} represents the vector of school characteristics, X_{pupils}, is the vector of pupils' characteristics and X_{teach}, is the vector of teachers' characteristics. The parameter of interest is γ which reflects the relation between teachers' test scores and their pupils' test scores.

Next we test whether the differences between teachers in terms of performance in ENADE can be explained by salary differentials observed between municipal school systems around the country. Again we estimate this partial correlation by OLS using the following model:

$$teach\_score = \alpha + \theta X_{system} + \sigma X_{teach} + \phi w_{teach} + \upsilon$$

where X_{system} is a vector of characteristics of the municipal school system; X_{teach} represents the vector of teachers' characteristics and w_{teach} is municipal teacher's salary.

After these two procedures, we obtain estimates for γ and ϕ, consisting of partial correlations between the performance of teachers and their pupils on tests and between teachers' performance and their remuneration.

Well founded in positive and statistically significant correlation between teachers' test scores in *ENADE* and pupils' test scores in *Prova Brasil* and between salaries and teachers' test scores. After we find these positive correlations, we compare the performance in ENADE of teachers working in municipal school system which had experienced salary hikes with the performance of teachers in municipalities that had not taken the treatment. It is important to notice that we are not able to precisely separate newly recruited teachers from the others. Thus the difference, whether it exists, may be a mixture of better recruitment and retention of teachers with higher performance in *ENADE*.

6 Results

We begin presenting results of the first exercise, the estimation of ATT on pupils' scores in 2009, the first year of the national minimum salary policy. Table 6 and Table 7 show results for test scores in Math and Portuguese, respectively, using models that consider as comparison group all municipal school system not treated, including those which were not impinged by the law, i.e. those that already pay in 2008 base salaries higher than the stipulated national minimum. ATT coefficients for Math have positive signals and the p-value decreases as long as more covariates are included in the estimation, but even in the full model (column 6) ATT coefficient is not statistically significant.

Table 6 ATT on Pupils' Math test scores (2007-2009) - broad control group

VARIABLES	(1) Restricted 1	(2) Restricted 2	(3) Restricted 3	(4) Restricted 4	(5) Restricted 5	(6) Full
ATT	1.525	1.525	1.623	1.770	2.304	2.226
	(0.671)	(0.520)	(0.492)	(0.451)	(0.253)	(0.262)
treated	-10.22***	-3.118*	-2.800	-2.510	-2.273	-2.343*
	(3.30e-06)	(0.0759)	(0.110)	(0.153)	(0.120)	(0.0988)
time	13.06***	13.06***	11.45***	10.97***	8.639***	8.718***
	(0)	(0)	(0)	(0)	(1.27e-10)	(7.82e-11)
Constant	193.1***	176.8***	160.8***	153.1***	88.71***	81.36***
	(0)	(0)	(0)	(0)	(2.20e-06)	(2.74e-05)
Observations	1,420	1,420	1,420	1,420	1,420	1,420
R-squared	0.116	0.624	0.632	0.644	0.720	0.725
Sample weights	YES	YES	YES	YES	YES	YES
Municipality characteristics		YES	YES	YES	YES	YES
School system chracteristics			YES	YES	YES	YES
School Infrastructure				YES	YES	YES
Pupils' characteristics					YES	YES
Political covariates						YES

pval in parentheses; sample weights considering stratified sample design.
*** p<0.01, ** p<0.05, * p<0.1

The effect on pupils' test scores in Portuguese with the model without covariates was estimated in 2.14 points. The introduction of covariates improves the efficiency of the estimation and the model with all covariates but the political ones, gives an ATT of 2.67 points, statistically significant at 10% level. However, when we include in the model political covariates, the coefficient stays exactly at 10% of statistical significance in the limit of rejection of the null hypothesis. One concern with this estimation procedure comes from the fact that the coefficient of the dummy which characterize treated units is statistically significant at 10% level. As shown in section 4, treatment and broad comparison groups are very distinct from each other in observables characteristics, what is probably reflected in poorer performance of treated municipal school systems.

Table 7 ATT on Pupils' Portuguese test scores (2007-2009) - broad control group

VARIABLES	(1) Restricted 1	(2) Restricted 2	(3) Restricted 3	(4) Restricted 4	(5) Restricted 5	(6) Full
ATT	2.140	2.140	1.931	2.025	2.669*	2.554
	(0.459)	(0.264)	(0.313)	(0.288)	(0.0923)	(0.100)
treated	-8.805***	-2.703*	-2.545*	-2.389	-1.885	-1.985*
	(2.44e-06)	(0.0727)	(0.0897)	(0.107)	(0.124)	(0.0947)
time	9.939***	9.939***	9.219***	8.774***	6.823***	6.899***
	(0)	(0)	(0)	(0)	(0)	(0)
Constant	173.6***	160.0***	147.6***	142.0***	92.79***	84.97***
	(0)	(0)	(0)	(0)	(2.28e-10)	(1.14e-08)
Observations	1,420	1,420	1,420	1,420	1,420	1,420
R-squared	0.110	0.636	0.644	0.658	0.750	0.755
Sample weights	YES	YES	YES	YES	YES	YES
Municipality characteristics		YES	YES	YES	YES	YES
School system chracteristics			YES	YES	YES	YES
School Infrastructure				YES	YES	YES
Pupils' characteristics					YES	YES
Political covariates						YES

pval in parentheses; sample weights considering stratified sample design.
*** p<0.01, ** p<0.05, * p<0.1

Using just municipal school systems impinged by the law but that refuse to comply with the national minimum salary as comparison group, we find no effects on proficiency in Math and Portuguese (see Table 8 and 9, respectively). Again treated has a smaller intercept than the comparison group in some specifications, mainly in Math test score.

Table 8 ATT on Pupils' Math test scores (2007-2009) - non compliers as control group

VARIABLES	(1) Restricted 1	(2) Restricted 2	(3) Restricted 3	(4) Restricted 4	(5) Restricted 5	(6) Full
ATT	2.611	2.611	2.820	2.824	2.566	2.595
	(0.534)	(0.315)	(0.262)	(0.254)	(0.216)	(0.206)
Treated	-3.353	-2.956	-3.367*	-3.602**	-2.989**	-2.781*
	(0.179)	(0.106)	(0.0578)	(0.0437)	(0.0423)	(0.0518)
time	11.97***	11.97***	11.13***	10.92***	7.668***	7.604***
	(8.12e-07)	(0)	(1.86e-09)	(1.78e-09)	(2.91e-06)	(4.23e-06)
Constant	186.2***	185.0***	173.7***	178.2***	90.28***	78.92***
	(0)	(0)	(0)	(0)	(7.65e-06)	(0.000111)
Observations	778	778	778	778	778	778
R-squared	0.092	0.610	0.621	0.633	0.721	0.727
Sample weights	YES	YES	YES	YES	YES	YES
Municipality characteristics		YES	YES	YES	YES	YES
School system chracteristics			YES	YES	YES	YES
School Infrastructure				YES	YES	YES
Pupils' characteristics					YES	YES
Political covariates						YES

pval in parentheses; sample weights considering stratified sample design.
*** p<0.01, ** p<0.05, * p<0.1

Table 9 ATT on Pupils' Portuguese test scores (2007-2009) - non compliers as control group

VARIABLES	(1) Restricted 1	(2) Restricted 2	(3) Restricted 3	(4) Restricted 4	(5) Restricted 5	(6) Full
ATT	1.909	1.909	1.842	1.850	1.496	1.449
	(0.563)	(0.357)	(0.358)	(0.356)	(0.360)	(0.368)
Treated	-2.255	-1.764	-2.272	-2.675*	-1.866	-1.629
	(0.266)	(0.248)	(0.120)	(0.0655)	(0.118)	(0.165)
time	10.17***	10.17***	10.16***	9.976***	8.004***	7.996***
	(1.40e-07)	(0)	(0)	(0)	(3.91e-10)	(5.20e-10)
Constant	167.0***	166.1***	160.3***	168.5***	102.7***	93.86***
	(0)	(0)	(0)	(0)	(1.97e-10)	(1.78e-08)
Observations	778	778	778	778	778	778
R-squared	0.096	0.620	0.632	0.647	0.749	0.756
Sample weights	YES	YES	YES	YES	YES	YES
Municipality characteristics		YES	YES	YES	YES	YES
School system chracteristics			YES	YES	YES	YES
School Infrastructure				YES	YES	YES
Pupils' characteristics					YES	YES
Political covariates						YES

pval in parentheses; sample w eights considering stratified sample design.
*** p<0.01, ** p<0.05, * p<0.1

In order to improve our identification, we adopt a selection on observables method allied with the DID. We estimate a propensity score (PS) of being treated with a probit model using two different matching procedure, Epanechnikov Kernel and Nearest Neighbor. Then the estimated PS were applied in the construction of new sample weights. In both cases, aiming to recover the ATT, we follow Abadie (2005) and weighted the observations in regression with the Inverse Probability of being Treated Weighting (IPTW) (Figure A.2 in Appendix compares PS balance between treated and untreated before and after weighting). Results of both propensity score matching method are similar, thus we present just the Epanechnikov Kernel in the following paragraphs. The results of the estimation through the IPTW-DID model using the broad comparison group are shown in Tables 10 and 11. Point estimates for ATT are generally higher, but they are not statistically significant for both Math and Portuguese test scores and in all of the specifications.

Table 10 ATT on Pupils' Math test score, Diff-in-Diff combined with selection on observables (2007-2009) - broad control group

VARIABLES	(1) Restricted 1	(2) Restricted 2	(3) Restricted 3	(4) Restricted 4	(5) Restricted 5	(6) Full
ATT	3.085	3.085	3.064	2.678	2.678	2.683
	(0.471)	(0.311)	(0.302)	(0.361)	(0.245)	(0.223)
Treated	-0.298	-3.714**	-3.810**	-3.736**	-2.576	-2.539*
	(0.900)	(0.0459)	(0.0373)	(0.0411)	(0.100)	(0.0886)
Time	11.50***	11.50***	9.789***	10.13***	7.129***	7.090***
	(6.65e-05)	(3.44e-07)	(7.40e-05)	(3.50e-05)	(0.000564)	(0.000446)
Constant	183.2***	187.9***	170.9***	173.9***	85.52***	82.33***
	(0)	(0)	(0)	(0)	(3.58e-05)	(8.76e-05)
Observations	1,416	1,416	1,416	1,416	1,416	1,416
R-squared	0.093	0.581	0.591	0.604	0.706	0.716
IPTW	YES	YES	YES	YES	YES	YES
Municipality characteristics		YES	YES	YES	YES	YES
School system chracteristics			YES	YES	YES	YES
School Infrastructure				YES	YES	YES
Pupils' characteristics					YES	YES
Political covariates						YES

pval in parentheses. IPTW: Inverse Probability Weighting considering stratified sample design.
*** p<0.01, ** p<0.05, * p<0.1

Table 11 ATT on Pupils' Portuguese test score, Diff-in-Diff combined with selection on observables (2007-2009) - broad control group

VARIABLES	(1) Restricted 1	(2) Restricted 2	(3) Restricted 3	(4) Restricted 4	(5) Restricted 5	(6) Full
ATT	2.827	2.827	2.372	2.082	2.045	2.032
	(0.438)	(0.289)	(0.368)	(0.419)	(0.278)	(0.265)
Treated	-0.299	-2.917*	-3.032*	-3.159*	-1.940	-1.947
	(0.885)	(0.0818)	(0.0655)	(0.0504)	(0.133)	(0.119)
Time	9.251***	9.251***	8.651***	8.762***	6.699***	6.727***
	(0.000389)	(7.44e-06)	(0.000117)	(6.23e-05)	(6.80e-05)	(3.61e-05)
Constant	165.1***	170.0***	156.1***	162.9***	103.5***	103.2***
	(0)	(0)	(0)	(0)	(2.97e-10)	(8.31e-10)
Observations	1,416	1,416	1,416	1,416	1,416	1,416
R-squared	0.090	0.585	0.595	0.610	0.728	0.735
IPTW	YES	YES	YES	YES	YES	YES
Municipality characteristics		YES	YES	YES	YES	YES
School system chracteristics			YES	YES	YES	YES
School Infrastructure				YES	YES	YES
Pupils' characteristics					YES	YES
Political covariates						YES

pval in parentheses. IPTW: Inverse Probability Weighting considering stratified sample design.
*** p<0.01, ** p<0.05, * p<0.1

Considering just non compliers as comparison group, results with selection on observables are similar to the previous ones, ATT have positive signals but are statistically not different from zero at 10% level of significance. Now the estimated coefficients for the treatment group are not statistically different from zero, reflecting a better matching between treated and comparison units (Figure A.4 in Appendix compares PS balance between treated and untreated before and after weighting).

Table 12 ATT on Pupils' Math test scores, Diff-in-Diff combined with selection on observables (2007-2009) - non compliers as control group

VARIABLES	(1) Restricted 1	(2) Restricted 2	(3) Restricted 3	(4) Restricted 4	(5) Restricted 5	(6) Full
ATT	2.403	2.403	2.060	2.217	2.897	2.920
	(0.658)	(0.531)	(0.576)	(0.527)	(0.239)	(0.213)
Treated	0.109	-3.318	-3.135	-3.491*	-2.360	-1.527
	(0.971)	(0.119)	(0.128)	(0.0917)	(0.153)	(0.364)
Time	12.90***	12.90***	12.08***	12.16***	7.653***	7.703***
	(0.00248)	(5.38e-05)	(0.000550)	(0.000248)	(0.00137)	(0.000627)
Constant	183.4***	179.8***	160.3***	170.8***	66.31***	44.82*
	(0)	(0)	(0)	(0)	(0.00602)	(0.0755)
Observations	1,278	1,278	1,278	1,278	1,278	1,278
R-squared	0.100	0.613	0.630	0.649	0.761	0.775
IPTW	YES	YES	YES	YES	YES	YES
Municipality characteristics		YES	YES	YES	YES	YES
School system chracteristics			YES	YES	YES	YES
School Infrastructure				YES	YES	YES
Pupils' characteristics					YES	YES
Political covariates						YES

pval in parentheses. IPTW: Inverse Probability Weighting considering stratified sample design.
*** p<0.01, ** p<0.05, * p<0.1

Table 13 ATT on Pupils' Portuguese test scores, Diff-in-Diff combined with selection on observables (2007-2009) - non compiers as control group

VARIABLES	(1) Restricted 1	(2) Restricted 2	(3) Restricted 3	(4) Restricted 4	(5) Restricted 5	(6) Full
ATT	1.749	1.749	0.867	1.143	1.524	1.548
	(0.706)	(0.628)	(0.793)	(0.705)	(0.429)	(0.400)
Treated	-0.827	-3.128	-2.925	-3.218*	-1.687	-0.856
	(0.746)	(0.135)	(0.117)	(0.0654)	(0.195)	(0.515)
Time	10.75***	10.75***	11.37***	11.11***	8.171***	8.038***
	(0.00426)	(0.000625)	(0.000226)	(8.46e-05)	(1.32e-06)	(1.13e-06)
Constant	166.2***	159.2***	152.9***	169.7***	91.71***	74.45***
	(0)	(0)	(0)	(0)	(3.47e-06)	(0.000210)
Observations	1,278	1,278	1,278	1,278	1,278	1,278
R-squared	0.100	0.597	0.623	0.649	0.783	0.796
IPTW	YES	YES	YES	YES	YES	YES
Municipality characteristics		YES	YES	YES	YES	YES
School system chracteristics			YES	YES	YES	YES
School Infrastructure				YES	YES	YES
Pupils' characteristics					YES	YES
Political covariates						YES

pval in parentheses. IPTW: Inverse Probability Weighting considering stratified sample design.
*** p<0.01, ** p<0.05, * p<0.1

In sum, for the first year of the policy, we could not reject the hypothesis that ATT for pupils' proficiency in Math is null, and, although the estimated ATT on test scores in Portuguese was positive and statistically significant at the level of 10% considering the broad comparison group, the results are not robust to other groups of control and to specifications with selection on observables.

However, the absence of significant impacts of raising teacher salaries on 5th graders proficiency in the first year after a salary hike does not mean that raising teacher salary has

no effect at all. It would be argued that, as education and learning are continuous and cumulative processes, the effects could require more time to prove. Therefore we extend our analysis to 2011 *Prova Brasil* test scores.

Our second exercise was to investigate if there is any impact of the salary hike on the proficiency pupils of the 5th grade after three school years. Using DID methods, we construct two different groups of treated units, a broad one, with all the compliers, indistinguishably, and another restricted treated group, without municipal school systems which complied with the law only in 2009 or only in 2009 and 2010. We could not reject the hypothesis that ATT is null whatever treatment and control groups are used in the second exercise.

Table 14 Effect of Raising Salary on Math test scores 2007-2011 (IV-DID)

VARIABLES	(1) math	(2) ln_math	(3) ln_math	(4) math	(5) math	(6) ln_math	(7) ln_math
Salary	-0.000593			0.0228	0.0135		
	(0.904)			(0.246)	(0.195)		
Salary log		-0.0175	0.00621			0.0732	0.0460*
		(0.653)	(0.822)			(0.103)	(0.0838)
Constant	112.8***	4.956***	6,0327***				
	(0)	(0)	(0)				
Observations	1,460	1,460	1,460	1,460	1,460	1,460	1,460
R-squared	0.687	0.687	0.689	0.576	0.6101	0.603	0.614
Complex sample design	Yes	Yes	Yes				
Instrument	binary	binary	continuous	binary	continuous	binary	continuous
Municipalities fixed-effects				Yes	Yes	Yes	Yes
First stage							
Instrument coefficient	-226.0229	-0.1723574	-0.0003858	82.5653	0.1934	0.1704754	0.0003769
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
R-squared	0.5275	0.5253	0.5491	0.7991	0.8057	0.8138	0.8435
(Kleibergen-Paap rk LM statistic):				10.321	21.567	57.28	75.731
(Kleibergen-Paap rk Wald F statistic):				10.331	27.896	70.234	153.223

pval in parentheses robust to clustering at municipal level.
*** p<0.01. ** p<0.05. * p<0.1

Alternatively we estimate ATT using an IV approach as described in Methodology section. First three columns of Table 14 present results for the 2SLS estimator, taking into account our complex sample for Math test scores. We could not reject the null hypothesis that there is not an effect of salary raise on Math test for all three models. The first stage becomes better when we include municipal school system fixed-effects in the model (column 4 on). Statistical tests show that instruments are strong in every specification. The continuous instrument, as expected, performs relatively better than the discrete one, and models in logs present higher point estimates, perhaps indicating a non linear relation between teachers' salary and pupils' proficiency. When we introduce school system fixed-effects the log-log model shows a statistically significant effect of teacher salary at 10% level of significance[55]. The result indicates that pupils' proficiency grows 0.05% in *Prova Brasil*

[55] We run the same regression models for the period 2007-2009 and we did not find statistically significant coefficients for ATT.

scale for each percent variation in teacher salary. In other words, a one percent variation in municipal teacher salary yields an increase of 0.4% of Math test score standard deviation, ceteris paribus. Or thinking backwards, to get an increase of one standard deviation a municipal school system should increase its teachers' salaries by 227%.

On the other hand, the effect of salary raise on proficiency in Portuguese were not statistically significant different from zero in all specifications as seen in Table 15.

Table 15 Effect of Raising Salary on Portuguese test scores 2007-2011 (IV-DID)

VARIABLES	(1) Port	(2) ln_Port	(3) ln_Port	(4) Port	(5) Port	(6) ln_Port	(7) ln_Port
Salary	0.00355			0.0132	0.00888		
	(0.430)			(0.417)	(0.311)		
Salary log		0.0106	0.0140			0.0502	0.0359
		(0.764)	(0.552)			(0.245)	(0.156)
Constant	93.59***	4.735***	4.714***				
	(0)	(0)	(0)				
Observations	1,460	1,460	1,460	1,460	1,460	1,460	1,460
R-squared	0.761	0.719	0.719	0.674	0.687	0.683	0.687
Complex sample design	Yes	Yes	Yes				
Instrument	binary	binary	continuous	binary	continuous	binary	continuous
Municipalities fixed effects				Yes	Yes	Yes	Yes
First Stage							
Instrument coefficient	-226.0229	-0.1723574	-0.0003858	82,5654	0,1933723	0,170475	0,00038
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R-squared	0.581	0.5253	0.5491	0.7971	0.8057	0.8138	0.8435
(Kleibergen-Paap rk LM statistic):				10,321	21,567	57,28	75,731
(Kleibergen-Paap rk Wald F statistic):				10,331	27,896	70,234	153,223

pval in parentheses robust to clustering at municipal level.
*** p<0.01. ** p<0.05. * p<0.1

We now turn to the results for the estimation of transmission channels. It could be the case that even if impacts do not happen yet, some mechanisms of transmission of salary increase to higher test scores are taking place. The same DID regressions were conducted to estimate some transmission channels. Firstly the focus is on the potential effect of salary raises on teachers' decision about leaving other working activities they may have. There is no effect of treatment on the proportion of teachers who are full-time teachers, i.e. who do not combine teaching with other paid jobs, in 2009. This result is not surprising for the first year of the policy since perhaps it takes more time for individuals to decide for leaving other activities after an improvement in the conditions of their teaching profession. However, no effect was found in 2011 either. Also no effect was found in the proportion of teachers who always or almost always correct pupils' homework according to their pupils report or the proportion of schools which suffer from teacher absenteeism in both years, 2009 and 2011.

Finally, we investigate whether the salary raise induced the recruitment and/or the retention of better teachers, assessed by their test scores in *ENADE*.

YET TO BE DONE

7 Concluding Remarks

This paper contributes to the debate on the effects of teacher salary raise on teachers' quality and the quality of the education provided by public school systems. For our purpose we take advantage of an exogenous variation of teacher salary in municipal school systems caused by the introduction of a minimum base salary in Brazil in 2008.

In the first year of the policy, although Brazilian municipalities witnessed a significant increase in teacher salaries, we do not find any effect on pupils' proficiency. However, after almost three years of the introduction of the policy it seems to have had an effect on pupils' performance on Math tests. In fact, we find a statistically significant effect on pupils' Math test scores only with 10% of significance level in an IV-DID approach. The estimated effect is equivalent to 0.05% of gain in test scores for each 1% increase in teacher salaries. In other words, if a municipal school system intends its pupils' average Math test scores to increase by one standard deviation, it should raise its teachers' salaries by 227%, ceteris paribus, a huge amount.

The results have to be interpreted in the given developing-country context where teachers' salaries are low relatively to developed countries and also relatively some competing activities. Although we find positive effects of raising teachers' salaries on pupils' performance, raising salaries of all teachers across the board, not attached to their effort and/or performance, raises concerns about the cost-effectiveness of the policy. We assess important effects of raising salaries on educational outcomes but further analysis should be done on the heterogeneity of the effects and on the cost-effectiveness of the policy.

In addition, we investigate some transmission channels through which higher salaries could lead to better pupils' performance. Namely, the recruitment and/or retention of most skilled teachers and the reduction of the number of teachers who combine teaching with other paid jobs. But no effect was found in any dimension.

We find no effect of treatment on teachers' scores during college. Next we plan to improve our identification strategy and investigate better this transmission channel to overcome some limitations of the current analysis. They include the lack of baseline information about teachers' knowledge and the small sample of teachers represented in the *ENADE* database.

We rely on two unique databases. First, aiming to circumvent limitations of existing databases, we carried out a survey with municipal education departments to get information about teachers' base salaries and career structures. We have other aspects and information obtained through this survey which we have not yet relied on and will be used in order to improve our results. Second, we connected teachers' test scores with teachers' base salaries and pupils' test scores, but unfortunately obtained a small teacher sample. We intend to enlarge that sample using other complementary databases.

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APPENDIX

Table A.1 Characteristics of the population of Brazilian municipalities – estimated from the weighted sample x real distribution

PANEL A - Comparison between sample, out of the sample and real population according to localization

Region	Municipalities with less than 200,000 inhab					Municipalities with 200,000 inhab or more				
	sample (A)	sample (weighted) (B)	out of sample (C)	total (D)	diff (B)-(D)	sample (A)	sample (weighted) (B)	out of sample (C)	total (D)	diff (B)-(D)
# obs	840	840	4600	5440		67	67	57	124	
N	11,9	7,71	7,41	8,11	-0,0041	2,99	4,53	10,53	6,45	-0,0192
					(0,0101)					(0,0355)
NE	25,71	31,37	33,74	32,5	-0,0113	14,93	22,52	28,07	20,97	0,0156
					(0,0173)					(0,0626)
SE	27,5	30,35	29,87	29,5	0,0085	58,21	51,91	42,11	50,81	0,0110
					(0 ,0169)					(0,0762)
S	20,48	22,67	21,63	21,45	0,0121	16,42	13,21	17,54	16,94	-0,0373
					(0,0152)					(0,0553)
MW	14,4	7,9	7,35	8,44	-0,0054	7,46	7,83	1,75	4,84	0,0299
					(0,0103)					(0,0358)

Note: Standard deviations in parenthesis.

PANEL B - Comparison between sample and the whole country according to characteristics

	sample (A)	sample (weighted) (B)	out of sample (C)	total (D)	diff (B)-(D)
Municipality characteristics					
# obs	907	907	4657	5564	
population (2007)	79.142	32.511	23.508	32.579	-68
st-dev	449.757	226.272	74.820	195.083	7.153
adult illiteracy rate (%)	13,9	15,4	16,6	16,2	-0,798**
st-dev	9,1	9,6	9,9	9,8	0,351
per capita GDP	10496,97	9061,274	9002,856	9246,459	-185,185
st-dev	8838,731	7301,328	10961,41	10657,84	367,189
RPPS	45,9%	35,8%	33,7%	35,7%	0,1%
					1,7%
School system characteristics					
# obs	902	902	4599	5501	
teachers pay/pupil (R$)	1457,37	1384,04	1380,19	1392,84	-8,80
st-dev	721,01	705,11	776,98	768,55	27,30
teachers pay/Fundeb resources (%)	72,499	71,647	71,687	71,820	-0,172
st-dev	12,271	12,002	12,337	12,329	0,441
budget spent on education (%)	28,727	28,937	29,893	29,702	-0,766**
	7,836	7,811	8,512	8,416	0,299
quantity of pupils	4200,5	2163,0	1841,5	2229,1	-66,1
st-dev	16932,0	8794,2	3882,5	7772,9	285,0
# obs	900	900	4578	5478	
Pupils' family background					
proportion of white pupils	36,6%	36,8%	35,6%	35,8%	1,0%
st-dev	16,6%	17,9%	17,5%	17,3%	0,6%
# obs	838	838	4149	4987	
possession of cars	36,4%	36,1%	33,5%	34,0%	2,16%**
st-dev	19,0%	20,4%	19,2%	19,2%	0,7%
# obs	838	838	4149	4987	
HH with fridge	91,2%	89,8%	88,0%	88,5%	1,27%***
st-dev	10,1%	11,0%	11,7%	11,5%	0,4%
# obs	838	838	4149	4987	
HH with internet access	12,5%	11,4%	10,7%	11,0%	0,3%
st-dev	9,1%	8,4%	8,4%	8,6%	0,3%
# obs	838	838	4149	4987	
mother with at least 12 years of shooling	25,5%	24,8%	24,3%	24,5%	0,3%
st-dev	10,4%	10,3%	11,6%	11,4%	0,4%
# obs	838	838	4147	4985	
leave with both parents	61,7%	60,9%	59,7%	60,0%	0,8%
st-dev	14,0%	16,4%	17,2%	16,7%	0,6%
# obs	837	837	4132	4969	
School infrastructure and facilities					
# obs	900	900	4580	5480	
computer for pupils	2,381	1,931	1,791	1,888	0,044
st-dev	4,410	3,949	3,795	3,909	0,141
schools with internet access	27,3%	24,7%	22,9%	23,6%	1,2%
st-dev	34,5%	33,7%	33,6%	33,8%	1,2%
schools with science laboratory	3,7%	3,2%	2,9%	3,0%	0,2%
st-dev	13,5%	13,7%	11,6%	11,9%	0,4%
restroom with accessibility	10,3%	7,7%	7,1%	7,6%	0,1%
st-dev	19,9%	18,3%	17,3%	17,8%	0,6%

PANEL C - Comparison between sample and the whole country according to variables of interest

	sample (A)	sample (weighted) (B)	out of sample (C)	total (D)	diff (B)-(D)
2005 Math score	179,1188	179,4492	176,5691	177,004	2,4452***
st-dev	16,55392	17,35767	17,6978	17,53241	0,6958
# obs	741	741	3604	4345	
2007 Math score	189,508	189,7538	187,1653	187,5581	2,1957***
st-dev	18,706	20,514	20,409	20,151	0,755
# obs	836	836	4150	4986	
2011 Math score	207,888	208,049	204,684	205,219	2,83***
st-dev	23,057	24,872	25,625	25,241	0,93
# obs	857	857	4279	5136	
Math score variation (2005-2007)	10,53	10,30	10,51	10,51	-0,212
st-dev	12,47	13,72	14,42	14,10	0,559
# obs	738	738	3592	4330	
Math score variation (2007-2011)	18,590	18,546	17,131	17,377	1,16832*
st-dev	16,594	17,975	18,854	18,498	0,696858
# obs	817	817	4022	4839	
2005 Portuguese score	170,708	170,003	167,113	167,726	2,2772***
st-dev	16,322	17,054	17,026	16,960	0,675
# obs	741	741	3604	4345	
2007 Portuguese score	170,8865	170,4286	168,3505	168,7757	1,6529**
st-dev	16,44666	17,84729	17,67715	17,50095	0,656
# obs	836	836	4150	4986	
2011 Portuguese score	187,578	187,116	184,301	184,848	2,268***
st-dev	18,565	20,003	20,775	20,458	0,753
# obs	857	857	4279	5136	
Portuguese score variation (2005-2007)	0,245	0,267	1,078	0,936	-0,669
st-dev	10,732	11,417	12,276	12,029	0,476
# obs	738	738	3592	4330	
Portuguese score variation (2007-2011)	16,939	16,993	15,647	15,865	1,12778**
st-dev	13,818	15,188	15,440	15,185	0,574
# obs	817	817	4022	4839	
Proportion of full-time teachers (2007)	59,52%	60,41%	60,07%	59,98%	0,43%
st-dev	28,75%	29,83%	29,33%	29,23%	1,10%
# obs	837	837	4131	4968	
Proportion of full-time teachers (2011)	57,24%	57,83%	59,22%	58,89%	-1,06%
st-dev	28,66%	29,17%	29,64%	29,48%	1,10%
# obs	830	830	4122	4952	
variation full-time teachers (2007-2011)	-2,05%	-2,30%	-0,90%	-1,09%	-1,21%
st-dev	35,88%	36,05%	35,83%	35,83%	1,38%
# obs	794	794	3893	4687	

Table A.2 Proportion of impinged and non-impinged municipal school systems by Region/State (%)

Region/ State	burdened (or impinged) no	yes
North	33,5	66,5
AC	64,6	35,4
AM	37,7	62,3
AP	0,0	100,0
PA	20,0	80,0
RO	23,3	76,7
RR	82,1	18,0
TO	42,4	57,7
Northeast	16,2	83,8
AL	51,2	48,9
BA	6,9	93,2
CE	16,4	83,6
MA	35,7	64,3
PB	7,6	92,4
PE	6,5	93,5
PI	20,2	79,8
RN	12,2	87,8
SE	21,2	78,8
Southeast	56,4	43,6
ES	21,2	78,8
MG	31,2	68,8
RJ	65,8	34,2
SP	95,1	4,9
South	50,4	49,6
PR	39,1	60,9
RS	66,8	33,2
SC	40,2	59,8
Mid-West	31,7	68,3
GO	24,7	75,3
MS	46,7	53,3
MT	35,9	64,1
Total	**38,8**	**61,2**

Table A.3 t-tests of difference of means between treated and untreated and between treated and non-compliers at baseline

	Treated (A)	Untreated (B)	Diff (A) - (B)	p-value		Non-compliers (C)	Diff (A) - (C)	p-value	
PANEL A Municipal characteristics									
Population (2007)	25.658	40.612	-14.953	0,03	**	21.494	4.165	0,23	
Per capita GDP	6.198	10.576	-4.378	0,00	***	8.273	-2.075	0,00	***
Adult illiteracy rate (%)	19,8	13,5	6,28	0,00	***	16,6	3,14	0,01	**
Region N	0,078	0,075	0,003	0,94		0,080	-0,002	0,95	
Region NE	0,558	0,234	0,324	0,00	***	0,362	0,196	0,00	***
Region SE	0,192	0,346	-0,153	0,00	***	0,240	-0,048	0,42	
Region S	0,112	0,257	-0,144	0,00	***	0,209	-0,096	0,06	*
Region MW	0,059	0,088	-0,029	0,08	*	0,110	-0,051	0,02	**
Active Munic Educ Council	0,623	0,773	-0,150	0,00	***	0,746	-0,123	0,04	**
School Council	0,755	0,789	-0,034	0,49		0,815	-0,060	0,29	
Fundeb Council	0,911	0,944	-0,033	0,36		0,929	-0,017	0,67	
Pro-mayor representatives	0,591	0,568	0,023	0,24		0,573	0,018	0,47	
2009 Mayor's reelection	0,230	0,321	-0,092	0,09	*	0,236	-0,007	0,91	
PANEL B School system characteristics									
Budget spent education 2008 (%)	31,3	29,2	2,1	0,0	**	29,7	1,6	0,11	
Budget spent/pupil - 2008 (R$)	2.712,9	3.374,9	-662,0	0,00	***	3.057,8	-344,9	0,01	***
Teachers pay/Fundeb - 2008 (%)	68,3	71,8	-3,44	0,00	***	69,7	-1,35	0,29	
Teachers pay/pupil - 2008 (R$)	1.102,9	1.414,0	-311,1	0,00	***	1.236,0	-133,1	0,02	**
Quantity of pupils	2.163,0	2.417,2	-254,1	0,40		1.748,8	414,2	0,13	
Quantity of teachers	75,4	98,3	-22,9	0,02	**	66,6	8,8	0,30	
Municipal school transp. system	0,220	0,279	-0,059	0,01	**	0,300	-0,080	0,01	***
Teachers' age (years)	35,9	36,7	-0,791	0,03	**	36,8	-0,920	0,02	**
Teachers' experience	6,2	6,7	-0,506	0,15		7,1	-0,848	0,05	*
Insufficient teachers in schools (2007)	0,025	0,043	-0,018	0,02	**	0,050	-0,024	0,03	**
Teacher absenteism (2007)	0,015	0,029	-0,013	0,04	**	0,031	-0,016	0,12	
Ful-time teachers (2007)	0,638	0,589	0,049	0,14		0,625	0,012	0,75	
Port teachers who correct hw (2007)	0,834	0,840	-0,005	0,72		0,847	-0,012	0,46	
Math teachers who correct hw (2007)	0,829	0,840	-0,011	0,29		0,835	-0,007	0,59	
Proportion of pupils with age-grade gap	0,467	0,384	0,083	0,00	***	0,428	0,038	0,07	*
PANEL C School infrastructure									
Restroom with accessibility	0,034	0,107	-0,074	0,00	***	0,053	-0,019	0,09	*
Schools with library	0,231	0,447	-0,216	0,00	***	0,328	-0,096	0,01	***
Schools with science laboratory	0,010	0,039	-0,029	0,00	***	0,024	-0,014	0,10	*
Schools with internet access	0,138	0,314	-0,177	0,00	***	0,187	-0,049	0,14	
Schools with TI laboratory	0,087	0,242	-0,155	0,00	***	0,151	-0,064	0,05	*
Computer for pupils	0,764	2,670	-1,905	0,00	***	1,413	-0,649	0,02	**
Schools without electricity	0,106	0,046	0,060	0,00	***	0,059	0,048	0,02	**
Schools not linked to sewage system	0,081	0,041	0,041	0,03	**	0,049	0,032	0,10	*
Schools not linked to garbage collection system	0,441	0,661	-0,220	0,00	***	0,511	-0,070	0,09	*
Schools without treated water	0,495	0,623	-0,128	0,00	***	0,509	-0,014	0,71	
Schools that provide meals	0,946	0,966	-0,020	0,15		0,976	-0,030	0,02	**

*** p<0.01, ** p<0.05, * p<0.1

Table t-tests of difference of means between treated and untreated and between treated and non-compliers (cont)

	Treated (A)	Untreated (B)	Diff (A) - (B)	p-value		Non-compliers (C)	Diff (A) - (C)	p-value	
Pupils characteristics									
Proportion of pupils who work	0,180	0,160	0,020	0,01	***	0,170	0,010	0,24	
Live with mother	0,220	0,212	0,008	0,46		0,207	0,014	0,29	
Live with both parents	0,588	0,624	-0,035	0,03	**	0,597	-0,008	0,69	
Illiterate Mother	0,094	0,071	0,024	0,01	***	0,087	0,007	0,51	
Mother with at least 12 years of schooling	0,240	0,257	-0,017	0,09	*	0,236	0,004	0,72	
HH with internet access	0,083	0,130	-0,047	0,00	***	0,099	-0,017	0,03	**
Proportion of white pupils	0,301	0,400	-0,100	0,00	***	0,352	-0,051	0,01	***
Proportion of male pupils	0,490	0,496	-0,007	0,47		0,489	0,001	0,94	
Possession of cars	0,267	0,403	-0,136	0,00	***	0,332	-0,065	0,00	***
HH with laundry-mashine	0,398	0,560	-0,162	0,00	***	0,482	-0,085	0,01	***
HH with fridge	0,862	0,921	-0,059	0,00	***	0,894	-0,032	0,01	***
HH with paid maid	0,120	0,114	0,006	0,29		0,114	0,006	0,30	
Proportion of pupils with pre-primary education	0,760	0,780	-0,021	0,09	*	0,762	-0,003	0,85	
HH with many books	0,254	0,257	-0,003	0,80		0,262	-0,008	0,54	
Crowded HH	0,272	0,223	0,048	0,00	***	0,246	0,026	0,07	*
Rural residents pupils	0,459	0,358	0,101	0,00	***	0,432	0,027	0,34	
Proportion of pupils who usually do Portug hw	0,754	0,768	-0,014	0,37		0,782	-0,028	0,12	
Proportion of pupils who usually do Math hw	0,785	0,792	-0,007	0,58		0,797	-0,012	0,48	

*** p<0.01, ** p<0.05, * p<0.1

Figure A.1 Standardized bias across covariates before and after matching on Propensity Score (broad untreated group)

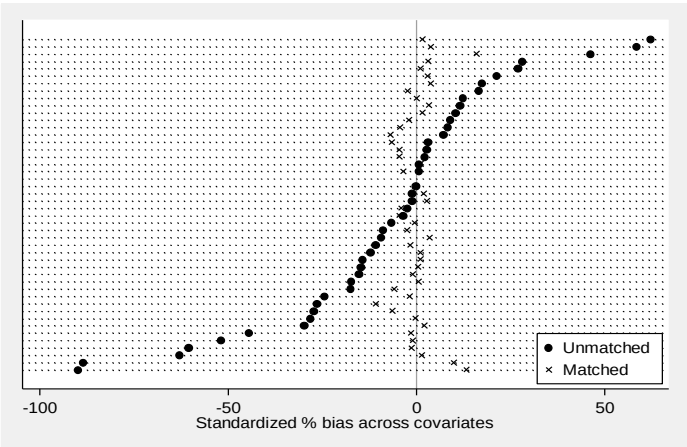

Figure A.2 Propensity Score density of treated and broad untreated

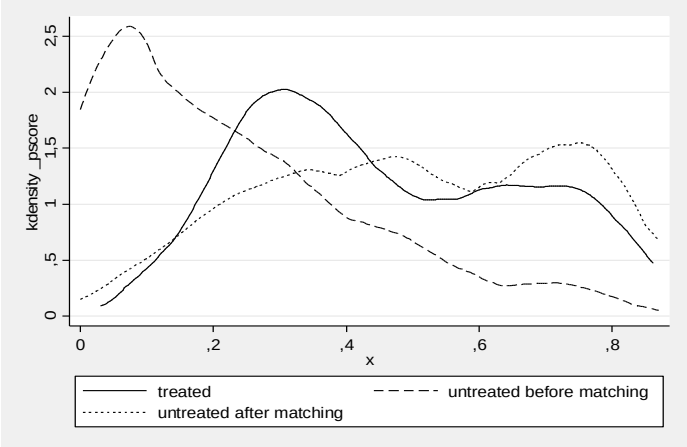

Figure A.3 Standardized bias across covariates before and after matching on Propensity Score (non-compliers as untreated group)

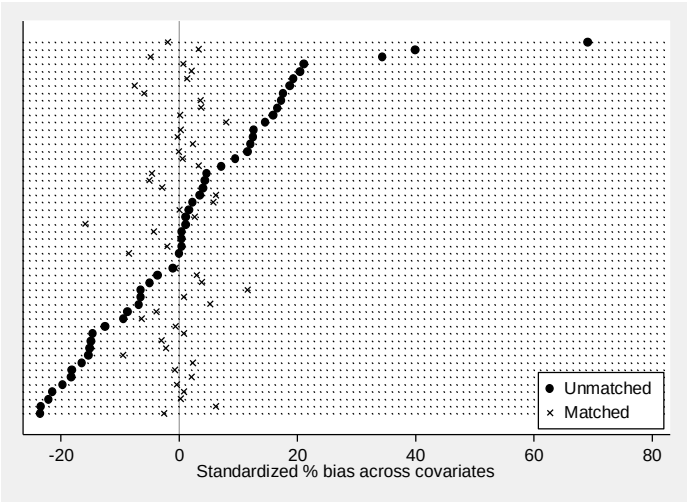

Figure A.4 Propensity Score density of treated and non-compliers