ROBERTA LOBODA BIONDI,
LÍGIA VASCONCELLOS,
NAERCIO MENEZES-FILHO

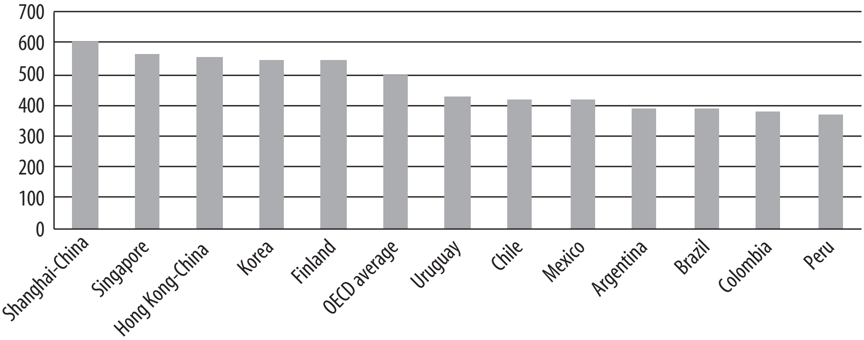
Evaluating the Impact of the Brazilian Public School Math Olympics on the Quality of Education

The current debate on education in Latin America centers on the need to raise the quality of education offered and to universalize school attendance. While many Latin American countries have achieved almost universal school attendance among children from 7 to 14 years of age, much remains to be done in terms of older and younger groups (López-Calva and Lustig 2010). With respect to educational quality, international test score results show that Latin American students tend to perform very badly in comparison with students in other countries. Figure 1, for example, compares average math test scores in several Latin American countries with those in high-scoring countries and with the OECD average, using the results of the latest (2009) PISA international evaluation. The figure shows quite clearly that the relative performance of Latin American students is dismal, even if one takes into account that the improvements in results over time in Brazil and Chile were among the greatest in this PISA.

Hanushek and Woessmann (2009) examines the importance of educational quality, measured by cognitive tests, for growth in various regions. The authors' estimated effects of cognitive skills are smaller in the Latin American subsample than in subsamples from other regions, but they are still important and statistically significant. Various government educational policies, along with initiatives from civil society and business, are aimed at addressing the questions of attainment and quality, but particular emphasis

Roberta Loboda Biondi is with EESP/FGV, Lígia Vasconcellos is with Itaú-Unibanco, and Naercio Menezes-Filho is with Insper and FEA/USP. This research was carried out as part of the Evaluation Program of Fundação Itaú Social. We thank the members of the IMPA board of directors, particularly Marcelo Viana and Eduardo Moacir Krieger, and the members of the LACEA editorial board, particularly Rodrigo Soares and Julian Cristia, for valuable comments.

FIGURE 1. Average Scores on the PISA 2009 Mathematics Test



Source: PISA (2010).

has been given to improving the quality of the education offered by public schools in Latin American countries (see Glewwe and Kremer 2006 for a review). This paper contributes to this literature by estimating the impact and analyzing the cost-benefit relationship of a specific educational program, the Brazilian Public School Math Olympics (OBMEP), a program aimed at encouraging better mathematics teaching and learning in Brazil.

Math olympics can be found in several countries around the world. One of the oldest programs is the International Mathematical Olympiad (IMO), which has run since 1959 and includes both public and private schools. In 2011, 101 countries took part in the IMO, with teams of around six participants (participants are high school students 19 years of age or less). The event is held in a different country every year. The main goal of the IMO is to identify and recognize the top young mathematicians in the world. It is expected that in the process of selecting their national teams, participating countries stimulate interest in mathematics in their country.

The United States and Colombia both conduct national math olympics, and both declare that the main objective of the competition is to bolster educational quality in general. In the United States, competitions are held for all school grades, and in Colombia, as in Brazil, participation is open to students in secondary school or above. The math olympics in other countries are open to all schools, both public and private.[1]

1. For more information, see Colombian Mathematics Olympiad (http://olimpia.uan.edu.co); Mathematical Olympiads for Elementary and Middle Schools (www.moems.org); American Mathematics Competitions (http://amc.maa.org); and IMO (www.imo-official.org).

TABLE 1. Schools and Students Participating in the OBMEP, First Phase

	Number of students			*Number of schools*[a]			
Year	*OBMEP participants*	*Total public school students*[b]	*Percent of participants*	*OBMEP participants*	*Public secondary schools*	*Public high schools*	*Percent of public secondary schools*
2005	10,520,831	24,373,817	43.2	31,030	46,700	16,570	66.4
2006	14,181,705	24,432,158	58.0	32,655	47,533	17,072	68.7
2007	17,341,732	23,302,080	74.4	38,450	49,327	17,576	77.9
2008	18,326,029	23,341,647	78.5	40,377	49,799	18,193	81.1
2009	19,198,710	23,073,958	83.2	43,654	50,397	18,508	86.6

Source: OBMEP (2011).
a. Some schools offer both secondary and high school grades. Numbers do not include schools offering adult education.
b. Enrollment in the low secondary and high school grades, which can participate in the OBMEP.

In Brazil there are two math olympics, run by the federal government. Brazilian Mathematics Olympics (OBM) includes public and private schools, and the Public School Math Olympics program restricts its focus to public schools. The latter, which is the focus of this study, has been promoted yearly since 2005 by the Ministry of Education and the Ministry of Science and Technology in partnership with the Institute of Pure and Applied Mathematics (IMPA) and the Brazilian Mathematical Society (SBM); the last two institutions are responsible for its academic direction. Students from secondary and high school can participate in the program.[2]

The stated objectives of the OBMEP are to stimulate and promote the study of mathematics among public school students; to contribute to the quality of basic education; to identify talented young people and encourage them to pursue careers in science and technology; to encourage the professional improvement of public school teachers; to contribute to the integration of public schools and public universities, research institutes, and scientific societies; and to promote social inclusion by spreading knowledge.

It is reasonable to assume that the OBMEP, given its objective to improve the quality of public math education and its scope in terms of geographic coverage and number of participants, could have a positive influence on the results of the public school assessments carried out by the federal government to measure educational quality, such as the Prova Brasil.

The number of participants in the OBMEP has been increasing over time: almost 20 million students participated in the first phase of the 2010 competition, and almost all municipalities in Brazil had at least one school enrolled (table 1). The number of students participating in the program is substantial

2. The Brazilian educational system is explained later in the paper.

when compared with the number participating in other educational programs in the country. Indeed, the program is considered one of the major competitions held among public school students in the country. The IMPA has an extensive team, organized into regional groups to operationalize the program, and rural as well as urban schools are included.

A booklet of sample questions and answers is sent to teachers at all schools that sign up for the math olympics. Its use is optional. It is intended not only to prepare students specifically for the olympics but also to have a positive influence on the overall teaching of math at the participating schools and thus on the performance of their students. This booklet is prepared by IMPA professors and SBM members to ensure its high quality.[3]

Our aim in this paper is to quantify the effects of the OBMEP on the quality of education received by Brazilian students by assessing its impact on the average math scores of the schools participating in the program on a standardized achievement test (Prova Brasil) and by calculating the economic return of the program by comparing its current costs with its future benefits to the students. Due to the availability of test scores, we focus on the impact of the 2007 OBMEP competition on the math test scores of the ninth-graders of that calendar year.

In light of the objectives of the math olympics, we pose this question: is it possible to identify in large-scale government evaluations an effect on the study of math in public schools of the incentives provided by the OBMEP? More specifically: does participation in the OBMEP bring a measurable improvement in average math performance at the participating schools? The econometric methodology that we use is linear regression, weighted by the propensity score in difference-in-differences specifications. The resulting estimator is doubly robust and points to a positive and statistically significant impact on the average math scores of ninth-graders on the 2007 Prova Brasil. Since the majority of schools participated in more than one OBMEP competition, we also investigated whether the impact is heterogeneous by number of participations.

We find an impact on the math test scores of participation in the OBMEP. The impact was greater for schools participating more than once. We also carried out estimations considering the percentiles of the distribution of student scores and found a significant effect, not only for better-performing stu-

3. For the IMPA statute and other statistics on the OBMEP, see www.obmep.org.br.

dents but also for those with lower scores, although the impact was relatively greater for higher achievers.

It is important to understand the mechanisms underlying this impact. Even if the math olympics is partially aimed at the most talented students, participation leads to improvements for the entire test score distribution, so its impact does not occur only through the incentives provided to the best students. Besides, we show that the results are stronger for schools that participate more than once. One possible channel is through teachers: they receive materials and their teaching may profit from them, increasing the quality of their classes in general. On the other hand, the evidence indicates that reading ability also seems to improve, so there must be an element of student motivation, possibly coming from the competition among them. It seems that OBMEP has been able to enhance not only the knowledge of teachers but also the motivation of students.

The OBMEP program seems to provide an extrinsic motivation for students—that is, they study in order to achieve a particular outcome, not for the joy of studying itself. The literature on incentives makes an important distinction between intrinsic and extrinsic motivation. Lepper, Corpus, and Iyengar (1995), for example, finds that the two kinds of motivation are necessarily correlated. In the authors' experiment, intrinsic motivation diminishes with age but extrinsic motivation does not. The problem is that when the extrinsic motivation (such as the prize) is gone, the effects of the program may dissipate, as observed in a meta-analysis in Deci, Koestner, and Ryan (1999). The best alternative would be to find a way to use the math olympics to increase intrinsic motivation so that it endures over the following years.

In the next section we describe the institutional background, data sources, and sample used in the empirical analysis. We then describe the strategies that we use to identify the impact of the OBMEP. Finally, we present the results and calculate the economic return of the program, with some assumptions on the future of students participating in the program.

Institutional Background, Data Sources, and Sample

The education system in Brazil is organized as follows. Basic education comprises twelve school years. The first five years include one grade that used to be preschool and four grades of so-called primary school; the next four grades could be compared with a low secondary school; and the last three grades are

TABLE 2. Number of Schools Signing Up for the OBMEP, by Level and Year, First Phase

	Level 1			Level 2			Level 3		
Year	Students signing up	Total enrollment in the public schools[a]	Schools signing up	Students signing up	Total enrollment in the public schools[b]	Schools signing up	Students signing up	Total enrollment in the public schools[c]	Schools signing up
2005	3,655,677	8,539,257	27,508	3,077,481	6,827,153	27,383	3,787,673	9,007,407	13,255
2006	4,851,150	8,584,864	29,766	4,026,207	6,789,770	29,132	5,304,348	9,057,524	14,277
2007	5,963,883	8,155,621	35,260	4,917,276	6,450,282	34,360	6,460,573	8,671,609	16,321

Source: OBMEP (2011).

a. Enrollment in grades 5 and 6 of secondary school.

b. Enrollment in grades 7 and 8 of secondary school.

c. Enrollment in high school.

secondary school or high school. Children have to begin school when they are six years old, and it is compulsory to finish low secondary school, no matter at what age.[4]

Most schools offering basic education are public schools (80 percent in 2009), which are known to be of lower quality than private ones. That is the major reason why there is a separate math olympics for public schools only. Children go to the schools in their neighborhood, provided there are vacancies. Teachers and principals are public servants; in general their salary increases with tenure, not with performance.

Potential participants in the OBMEP are students in grades 6 through 12. Students who sign up are divided into the following levels: 1 (students enrolled in grades 6 or 7); 2 (students enrolled in grades 8 or 9, including adult education students); and 3 (students enrolled in grades 10, 11, or 12). See table 2 for the distribution of the students among the levels.

The math olympics occurs in two phases. In the first, all public schools can sign up voluntarily to participate with their students at any or all of the three levels, depending on the grades offered at the particular school. At that time each school receives the booklet of sample questions and answers. In this phase tests are given and corrected at each participating school, which can send the top 5 percent of its students to take part in the second phase of the competition. Students receiving a score of zero in the first phase are not classified for the second phase.

4. The duration of basic education in Brazil changed in 2010 from eleven to twelve years. Children now enter school sooner, at six years of age instead of seven.

Most schools that participate in the OBMEP do so repeatedly. Moreover, considering the OBMEP for 2007 at level 2, the proportion of students participating in relation to total students enrolled in participating schools was very high. The median of that proportion among all the participating schools was 94 percent, and in the first quartile of the distribution the proportion was 75 percent. This shows that even though one of the goals of the math olympics is to identify high-performance students, schools tend to sign up the great majority of their students in the first phase.

Just before the start of the registration period, the OBMEP is widely advertised on websites, on television, in newspapers, and on radio stations by the agencies responsible for organizing the competition (the Ministry of Education and the Institute of Pure and Applied Mathematics). In addition, all public schools are mailed a notice with the timetable for the OBMEP. The principals and math teachers choose whether to enroll their students in the competition. After enrollment, they receive a booklet including instructions for the OBMEP and a sample of math problems and solutions, which is meant to help teachers to train their students. However, its use is optional and there is no record of use.

We believe that the participation of schools in the OBMEP is related to characteristics such as location, size of the local municipality, socioeconomic conditions, number of students enrolled, and participation in other government programs in addition to features specific to principals and teachers. Better informed and trained teachers and principals, for example, may be more likely to enroll their students in OBMEP. In the empirical analysis, we assume that teachers' and principals' motivation to enroll students in OBMEP is related only to their experience, age, education, and other observable features.

Data Sources

To analyze the impact of the OBMEP, we used as an indicator the score on the 2007 Prova Brasil, a standardized assessment test given since 2005 to all urban public school students in the country every two years by the National Educational Research Institute (INEP), part of the Ministry of Education (MEC). This evaluation is censitary, ensuring that scores are representative for the schools. The test is given to students in grades 5 and 9 of all urban schools with at least twenty students enrolled in each grade. The Prova Brasil methodology is based on the item response theory (IRT), which allows comparison of the scores in reading (Portuguese) and mathematics of students in different grades and over time. Moreover, teachers, principals, and students answer a quite complete socioeconomic questionnaire, which we use in the

TABLE 3. Sample

Item	*Number*	
Active public schools in Brazil (2006)	168,436	
Potential OBMEP participants (level 2)	68,961	
	Treated schools *Signed up for the 2007 OBMEP*	*Comparison schools* *Nonparticipants in the 2007 OBMEP*
All schools	34,222	34,739
Participants in the 2007 Prova Brasil	22,996	4,052
Final sample after the filters[a]	22,703	1,756

Source: OBMEP (2011).

a. Treated schools: we defined as a minimum threshold 10 percent of students regularly enrolled in grades 8 and 9 who signed up to take the first phase of the OBMEP. This cut-off criterion eliminated only 293 schools in the treatment group. Comparison schools: we kept in the sample only those schools that had never participated in the OBMEP. This criterion eliminated 2,296 schools.

empirical exercises below. The infrastructure characteristics and educational indicators of the schools used as controls come from the 2006 School Census, and the municipal population and per capita income figures come from the 2000 Demographic Census (IBGE 2000).

The impact evaluation therefore is restricted to urban schools that administered the 2007 Prova Brasil to ninth-graders. Since it was impossible to identify the students that participated in the program and their scores on the Prova Brasil, we used the average score of each school as the outcome of interest. In other words, our unit of observation is the school, not the student.

The schools sign up for the OBMEP at the start of the school year (February), and the tests in the first phase are given at the start of the second semester (middle of August). The second phase occurs in October or November. The 2007 Prova Brasil was given to students in November of that year, so the results may have been influenced by the OBMEP.

The Sample

Of the 168,436 active public schools in Brazil (2006 School Census), 68,961 were potential participants in the OBMEP at level 2—that is, they had students enrolled in grades 8 or 9 or offered adult education programs at the equivalent grade level.[5] However, only 34,222 of those signed up for the competition, and not all of them participated in the Prova Brasil. Table 3

5. This sample includes schools that offer adult education, hence the difference with respect to table 1, which does not.

presents the sample of schools in the treatment group (participants in the 2007 OBMEP) and comparison group (nonparticipants in the 2007 OBMEP). Of the 34,222 schools participating at level 2 of the OBMEP in 2007, 22,996 participated in the Prova Brasil in 2007.

Of the 68,961 schools that could have participated in the 2007 OBMEP, 34,739 did not do so, making them candidates for the control group. However, of those only 4,052 took part in the 2007 Prova Brasil. Failure to participate was due to the fact that 58 percent of the schools were rural and most of the remainder did not have more than twenty students in the ninth grade. In addition, we removed from the sample of treated schools those that signed up less than 10 percent of their students for the first phase (however, few schools were eliminated from the sample on that basis).

The small sample size of the control group is mainly due to the fact that schools that did not participate in the OBMEP in 2007 were located in municipalities in rural areas. In fact, this feature affected the control group more than the treatment group, indicating that schools that decided to participate in the OBMEP were predominantly urban. Moreover, of the 4,052 schools in the control group that participated in the 2007 Prova Brasil, 2,296 participated in some OBMEP competition before 2007 and therefore were also excluded from the sample. Thus, 1,756 schools formed the control group.

Table A in the appendix compares the statistics of the schools participating in the OBMEP with those of nonparticipating schools in this sample. It shows that even after the sample is restricted to urban and bigger schools, the treated schools are larger, have more students and teachers, and also have relatively better average student characteristics, such as higher percentages of students who had at least one parent that completed college, who went to preschool, who do not work, and who were never held back. This is reflected in the average scores on the Prova Brasil: in both years analyzed and in both subjects (Portuguese and math), the scores of the schools that signed up for the OBMEP were higher.

By directly comparing the average score of treated schools with that of untreated schools without first ensuring that the two groups are similar with respect to other characteristics, we would obtain a biased estimate of the impact of OBMEP on students' test scores. Below we explain the strategy adopted to correct this problem by weighting the schools of the control group according to their similarities on observable characteristics to schools in the treatment group.

Impact Evaluation Methodology

To infer the quantitative effect of the OBMEP on the average math scores of the schools that signed up for the program, we need to know what those schools' scores would have been had they not taken part in the competition. This question brings up the problem of the unobserved counterfactual, because obviously we cannot observe the math scores of the students participating in the OBMEP if they had not participated. To address this question and to avoid the problem of selection bias, we need a control group (nonparticipating schools) that is similar to the treated schools (participants in the OBMEP) for the counterfactual.

Formally stated, we define Y_0 as the potential result of a particular school if it did not sign up for the OBMEP and Y_1 as the potential result of that school if it did sign up, and we say that $T = 1$ when the school signed up and $T = 0$ when it did not. We can observe $Y_1|T = 1$ and $Y_0|T = 0$, but we never observe $Y_1|T = 0$ and $Y_0|T = 1$. We want to know the difference between the score obtained by schools that signed up for the program and the score that they would have received had they not signed up. We can write this as $D = E[Y_1|T = 1] - E[Y_0|T = 1]$.

What we are really observing is $G = E[Y_1|T = 1] - E[Y_0|T = 0]$, so the difference between these terms gives us the selection bias $B = G - D = [Y_0|T = 1] - E[Y_0|T = 0]$. This bias arises if the control group is inadequate, such as when the schools that did not sign up for the program were very different from those that did. Since signing up for the OBMEP is voluntary, inclusion in the treated or control group is not random; a potential problem of selection bias therefore arises.

In response, we use a control group with characteristics similar to those of the treated group, working with the hypothesis of selection on observables. This hypothesis appears reasonable since we have many variables reflecting school management, infrastructure, teaching staff, and student body, among others. In addition, we observe the schools' test scores before the 2007 OBMEP, so we can use the difference-in-differences specification to control for differences in scores before the treatment. This has the advantage of controlling for unobservable characteristics that do not change over time. Hence, the estimate of the average effect of treatment on the treated (ATT) will be more reliable.

Applying adequate econometric methods, we can use this rich set of characteristics to predict the conditional probability of receiving the treatment among all the schools in the sample, which allows us to find a control group that resolves the potential selection bias problem. Assuming the matrix X is a set of observable characteristics that determine participation in the treatment and its result, the key hypotheses to eliminate selection bias are as follows:

(a) $Y_0 \perp T|X$, that is, independence of the potential results in relation to the treatment, given the characteristics of the observables (treatment ignorability assumption)

(b) Implicit common support hypothesis: $0 < Pr(T = 1|X) = p(X) < 1 \ \forall X \in \chi$, where χ is the support of the distribution of X. There is no value of X for which one can say for sure to which group (T = 1 or T = 0) it belongs.

These two hypotheses are known as strong ignorability. Rosenbaum and Rubin (1983) showed that given (a) and (b), the following also holds:

(c) $Y_0 \perp T|p(X)$, where p(X) is the probability of being treated given X, or the propensity score. This hypothesis reduces the dimension necessary to resolve the matching.

The identification assumption thus depends on there being no unobservable variables for the treated group and the control group that affect the schools' results differently.

The current econometric literature contains various methods based on propensity scoring to infer causality between a treatment and the result. One of the best known is propensity score matching, whereby the treated units are matched with the control units according to their estimated probabilities, assuming some hypothesis on functional forms. The use of the propensity score has the advantage of reducing the dimensional size of the covariates, facilitating their operationalization. However, the literature contains criticisms of this method. The main bone of contention is that the function p(X) is estimated and that it can affect the variance of the estimator in the matching. Because it is impossible to know the distribution of the propensity score, the standard errors of the estimators may be unreliable.

We therefore used linear regression with estimated propensity score weighting to find the estimate of the average effect of the treatment on the treated. The idea is to attribute different weights to the schools in the control group according to their characteristics and probabilities of participating in the OBMEP. According to the econometric literature, this method has advantages over others based on the propensity score, mainly with respect to the estimator's efficiency even when a functional form is imposed to estimate p(X).[6]

We implemented this method of combining regression with propensity scoring weighting in two steps. In the first step we estimated $\hat{p}(X) = pr(T_i = 1|Xi = x)$ from a binary response model, assuming a standard logistic distribution (logit) function. In the second step we used a linear regression of Y_i (math score) on T_i and X_i weighted by a function of the treatment and nontreatment probabilities resulting from the estimation in the first step. We report results with the dependent variable in levels,

$$(1) \qquad Y_{i,l,2007} = \alpha_1 + \gamma TREAT_{i,l,2007} + X'_{il}\beta_1 + \eta_1 Y_{i,l2005} + P'_{i,l}\delta_1 + T'_{i,l}\lambda_1 + S'_{i,l}\varphi_1 + M'_{m,l}\phi_1 + DR'_l\theta_1 + u_{i,l}$$

and in differences (also known as a difference-in-differences model),

$$(2) \qquad \Delta Y_{i,l,(2007-2005)} = \alpha_2 + \gamma TREAT_{i,l,2007} + X'_{il}\beta_2 + P'_{i,l}\delta_2 + T'_{i,l}\lambda_2 + S'_{i,l}\varphi_2 + M'_{m,l}\phi_2 + DR'_l\theta_2 + \varepsilon_{i,l},$$

where $TREAT_{i,l,2007}$ is a dummy variable that identifies whether the school i located in the region l participated in the OBMEP in 2007; $Y_{i,l,2007}$ is the average math score on the Prova Brasil 2007 of ninth-graders in the school i located in the region l; $\Delta Y_{i,l,(2007-2005)}$ is the mean difference in math scores between the years 2007 and 2005 on the Prova Brasil of ninth-graders in the school i located in the region l; $Y_{i,l,2005}$ is the average math score on the Prova Brasil 2005 of ninth-graders in the school i located in the region l; $X_{i,l}$ is a vector of covariates on the characteristics of the school i located in the region l; $P_{i,l}$ is a vector of covariates on the characteristics of principals in the school i located in the region l; $T_{i,l}$ is a vector of covariates on the characteristics of teachers in the school i located in the region l; $S_{i,l}$ is a vector of covariates on the characteristics of students in the school i located in the region l; $M_{m,l}$ is a vector of covariates on the characteristics of the municipality in which the school operates; DR_l are dummy variables that identify whether the school i belongs to the lth region; and $\varepsilon_{i,l}$, and $u_{i,l}$ are IID error components.

6. For more details on the impact methodologies, see also Imbens and Wooldridge (2008).

The weighting is given by

$$w_i = \frac{\hat{p}(x_i)}{p} \circ \frac{1-p}{1-p(x_i)} \circ \frac{1-T_i}{1-p} \text{ for the untreated observation and} \tag{3}$$

$$w_i = \frac{T_i}{p} \text{ for treated observation,} \tag{4}$$

where $p = \sum_{n=1}^{n1} \hat{p}(X) \middle| T=1,$ and n1 = number of treated units.

The resulting estimator can be defined as doubly robust according to the estimators developed in Robins and Rotnitzky (1995).[7] In explaining the advantages of the method combining regression and propensity score, Imbens and Wooldridge (2008) drew an analogy to the omitted variable bias problem. Suppose one's interest is to estimate the coefficient of the treatment in a linear regression of Y_i on T_i, X_i and a constant. Upon carrying out a regression of Y_i only on T_i and the constant, a bias is produced, equal to the product of the coefficient of X_i of the long regression and the coefficient of X_i in a regression of T_i on a constant and on X_i. The weighting factor can be interpreted as the factor that removes the correlation between T_i and X_i, and the linear regression can be interpreted as the factor that removes the direct effect of X_i. As a result, by removing the correlation between the omitted covariates and by reducing the correlation between the omitted and included variables, this estimator leads to additional robustness not found in other methods based on the estimated propensity score.

To choose the set of variables X used to estimate the logit and the weighted regression of Y_i on T_i and X_i, we used the method of "stratification by estimated probability" proposed in Dehejia and Wahba (1999). Within each stratum we verified the balancing of each component of X between the treatment and control groups. This method ensures efficient estimation of $\hat{p}(X)$. We divided the sample into four strata according to the estimated $\hat{p}(X)$ and tested the balance of each component of X. For cases of imbalance, we performed iterations or changed the model's functional form until all the included variables were balanced.

7. See also Robins, Rotnitzky, and Scharfstein (1999).

The last column in table A of the appendix shows the t statistics of the balancing test. It can be seen that there are no significant differences between the treatment and control groups when the samples are divided by strata of $\hat{p}(X)$, proving that the distribution of the included variables is balanced between the two groups.

The covariates included in the model are the infrastructure and teaching conditions of the schools (average class size, average number of hours per day, school size), characteristics of the municipalities where they are located, and information on the students. The student data, which were taken from the socioeconomic questionnaire of the Prova Brasil, contain important information on the profile of the students attending the treated and untreated schools. We also included dummies to identify the different regions of Brazil where the schools are located. We included the math scores for 2005 on the Prova Brasil because each school's raw score in the evaluations can supply relevant information not captured by the other school inputs considered in the model, such as school quality or management. These can influence the probability that a school participates in the OBMEP, so it can be correlated with the result of the math evaluation.[8] In the difference-in-differences model, instead of using the students' characteristics in levels, we considered their variations between 2005 and 2007 to capture changes in student profiles that could be related to their performance.

In the first step of the method, the explanatory power of the logit with the inclusion of all covariates was 12.9 percent (see table B in the appendix). Most of them were significant at 10 percent in explaining participation in the OBMEP, except the following (seven of twenty-eight variables): municipality's per capita income; whether school is a municipal rather than a state school; high teacher turnover; interruption of school activities; and three student profile variables (race, sex, and previous attendance in preschool).[9] In the next section we present the results of the impact evaluation.

8. In this way, we restricted the sample and the results found to schools that participated in the 2005 and 2007 Prova Brasil.

9. We performed another test to see whether the variables included fit well with the probabilities of participation for the treated and untreated schools. To do this, we compared the distributions of $\hat{p}(X)$ before and after matching. The distributions were very similar, demonstrating that the variables included ensure good-quality matching. Figure A in the appendix compares the density kernel distributions before and after matching for the treated and control schools.

TABLE 4. Impact of the 2007 OBMEP on Math Scores[a]

Item	*Difference in means*	*ATT (level)*	*ATT (difference-in-differences)*
Coefficient	7.44*	2.27*	1.91*
	(0.68)	(0.57)	(0.58)
Number	24,459	14,778	14,778

Source: Authors' calculations.

a. Robust standard error in parentheses. Dependent variable: average ninth-grader math score in 2007 (level) and differences between 2007 and 2005 (difference-in-differences). Doubly robust estimator. Controls are the characteristics of schools, districts, principals, teachers, and students, plus regional dummies.

*Significant at 1 percent.

Results

The results presented here refer to the impact of schools' participation in the 2007 OBMEP on the average math score of ninth-grade students on the Prova Brasil for 2007. As mentioned in the methodology section, combining regression and propensity score weighting is valid to eliminate the selection bias, under the assumption of selection on observables. The most reliable estimates are the difference-in-differences ones, but they could be underestimated because some schools had participated since 2005 and their scores for 2005 could already have been influenced by their participation. Hence, the estimates by this method control for the potential problems of bias more adequately, but they can underestimate the impact found.

Table 4 shows the simple score difference and the results of the average treatment effect on the treated in levels and in differences.[10] The difference between the average scores of treated and comparison schools in 2007, without any controls, is 7.44 points. In contrast, the ATT levels estimate is 2.27 points, and the difference-in-differences estimate is 1.91 (equivalent to 10 percent of the standard deviation of the school test scores), all of which are statistically significant at 1 percent. Table C in the appendix presents the results of the second step, according to equations (1) and (2), for the scores in differences.

The results presented in table 4 could be interpreted as the average impact of participating in the 2007 OBMEP, independent of the number of times

10. The complete set of results is presented in table A of the Appendix. We also carried out the estimates using the more traditional propensity score matching method. The results had the same sign and significance of those presented here.

TABLE 5. Number of Times That Schools Participated in the OBMEP

Number of times	*Number of schools*	*Percent*
One	1,960	9
Two	5,104	22
Three	15,639	69
Total	22,703	100

Source: OBMEP (2011).

that the schools participated in previous years. As stated before, most of the schools that participated in the OBMEP in 2007 also did so in at least one previous year. Table 5 shows the distribution of schools by the number of times that they had participated in the OBMEP since 2005. We also performed estimates based on this distribution to distinguish the impact according to the number of times that they participated in the three versions of the OBMEP from 2005 to 2007. We constructed three samples: the first considered as treated the schools that participated only in 2007; the second considered as treated only the schools that participated twice (in 2006 and 2007 or 2005 and 2007); and the third considered as treated only the schools that participated in all three years. The control group in each case was composed of the schools that never participated in the OBMEP. We applied the same method and set of variables explained before, both in the in-levels and difference-in-differences specifications. Table 6 summarizes the results.

The ATT estimates show positive and statistically significant impacts and indicate that the higher the number of participations in the OBMEP, the

TABLE 6. Impact by Number of Times That Schools Participated[a]

Number of times	*Difference in means*	*ATT (level)*	*ATT (difference-in-differences)*	*Number of schools (treated x control)*	
One	2.29**	0.07	0.13	1,960	1,756
	(0.83)	(0.56)	(0.63)		
Two	4.24**	1.45**	1.30*	5,104	1,756
	(0.70)	(0.53)	(0.58)		
Three	9.34**	2.63**	2.28**	15,639	1,756
	(0.64)	(0.63)	(0.61)		

Source: Authors' calculations.

a. Robust standard error in parentheses. Dependent variable: average ninth-grader math score in 2007 (level) and differences between 2007 and 2005 (difference-in-differences). Doubly robust estimator. Controls are the characteristics of schools, districts, principals, teachers, and students, plus regional dummies.

*Significant at 5 percent; **significant at 1 percent.

TABLE 7. Robustness[a]

Item	*Fifth-graders*	*Trimming*	*Reading*	*Triple differences*	*Dropping 2005 Schools*
Coefficient	1.13	1.56**	1.12*	0.79	0.96*
	(0.96)	(0.55)	(0.63)	(0.51)	(0.57)
Number	8,934	14,778	14,778	14,778	4,742

Source: Authors' calculations.

a. Robust standard error in parentheses. Standard errors estimated by the Eicker-White procedure. Dependent variable: difference in math scores between 2007 and 2005 (difference-in-differences). Estimates are results of the doubly robust estimator. Controls are the characteristics of schools, districts, principals, teachers, and students, plus regional dummies.

*Significant at 10 percent; **significant at 1 percent.

greater the effect on the school score. The difference-in-differences estimate shows a 1.30-point impact for two participations and a 2.28-point impact for three participations. The nonsignificant impact for the few schools that participated only in 2007 indicates that the treatment needs time to spread its effect among all students (remember that the 2007 test score is applied in the end of 2007, at the very moment that the OBMEP itself is at its final steps).

Robustness

There are several concerns about our main results, presented above. The most important one is endogeneity, as schools becoming better over time may, at the same time, decide to enroll in the OBMEP. We also want to understand better the mechanisms driving our main results. Therefore we performed several robustness checks, displayed in table 7.

As a placebo test, we examined whether we would obtain the same result for a population that was not directly exposed to the treatment although it was related to the group of schools that did receive the treatment. In order to do that, we used as a new dependent variable the math scores of the fifth-grade students of the schools that participated in the OBMEP in 2007. These students were not directly exposed to the treatment, since the OBMEP is not offered to students before the sixth grade. Besides, according to the Brazilian school system, primary teachers (teaching until the fifth grade) are not allowed to teach the upper grades and vice versa, so there should be no externality of impact in this way. A positive impact would indicate that unobserved variables may be influencing (biasing) the results for the ninth-graders. The first column of table 7 shows that the impact was not statistically significant.

To examine the importance of outliers to the results, we trimmed the 1 percent top and bottom math test score distributions from 2005 and 2007.

The results remained qualitatively the same, positive and significant in the difference-in-differences specification, as the second column of table 7 shows.

We now examine whether the math competition influences performance in other subjects. As we also have the reading (Portuguese) test scores from Prova Brasil, we performed the same empirical exercises using a different outcome. The idea was to examine whether the incentives for one subject might influence others as well and, if so, in which direction. The third column of table 7 shows the results. There is a positive impact in the reading tests, though smaller in magnitude and only marginally statistically significant. In light of this result, we also considered a triple difference estimate, controlling in addition for the reading score change (fourth column). The result shows that the triple difference impact on math is no longer significant. Therefore, it seems that the OBMEP brought about a positive externality that was probably related to students' motivation to learn, which spread to other disciplines as well. Another interpretation of this result is that the reading scores are in fact controlling for other omitted school variables that trend positively over time. That would mean that the math results presented so far are to be seen as an upper bound of the true impact, with the triple-differences result of this table being the lower bound.

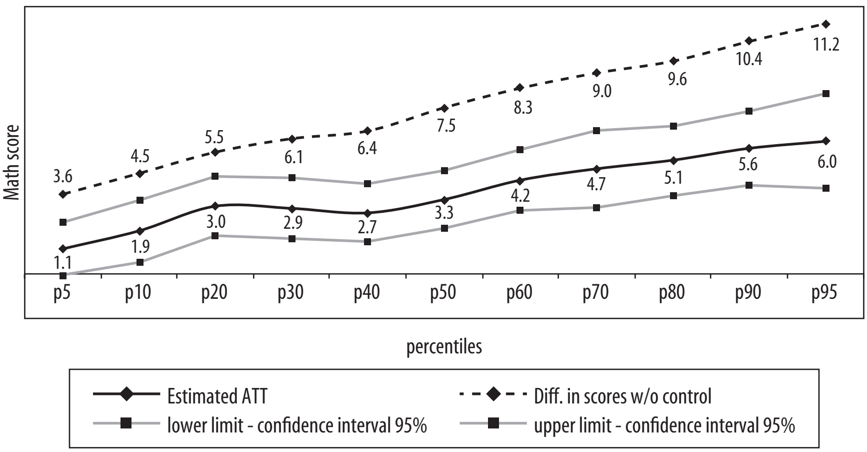
Another important issue is that some schools in the treatment group already participated in the OBMEP in 2005 (baseline). Therefore, we ran another robustness check, excluding from the treatment group the schools that participated in all three competitions and keeping only the schools that participated both in 2006 and 2007. The fifth column shows that the difference-in-differences impact for this sample is marginally statistically significant.[11] It seems, therefore, that most of the impact of OBMEP comes from the sample of schools that participated in all three years, which, in effect, represent almost 70 percent of the sample, as table 5 shows.

Heterogeneity

One of the objectives of the OBMEP is to identify young people with a talent for math in order to give better opportunities to such youths who come from adverse socioeconomic conditions. According to the rules, only the students with scores in the top 5 percent continue to the second phase of the OBMEP. Therefore, we calculated estimates separately, considering the student scores

11. No significant impact was found for the subsample that includes treatment schools that participated only in 2007, however.

FIGURE 2. Estimates of the Impact of the OBMEP, by Math Score Percentiles



Source: Table 8, in text.

in specific percentiles as the result variable, to shed light on whether there is a difference in the impact depending on higher or lower student scores on the Prova Brasil.

From the distribution of math scores of all ninth-graders, we calculated the scores in the deciles of the distribution and also in the 5th and 95th percentiles and used them as results in the impact estimates. For each percentile we applied the same methodology and same set of observable characteristics as described previously, considering all the schools participating in 2007, irrespective of the number of times that they participated. Figure 2 depicts the results.

The solid bold line shows the ATT estimates in the percentiles. All the results are significant and positive for all levels, indicating that the OBMEP improves the scores of all students. However, the effect is stronger for the higher percentiles, with impacts ranging from 1 to 6 points on the math score. The dotted line depicts the difference in the simple average between the scores of the treated and control schools, which increases more sharply than the impact of OBMEP.

Table 8 shows the average scores observed in the treatment and control schools in each percentile, the estimated ATT, and the ratio between the ATT and the average score of the control schools. The results here show that the relative impact is greater for students with better performance on the Prova

TABLE 8. Math Score Percentiles: Average Treated and Control Schools, ATT and Relative Impact[a]

Percentiles	*Score of the participating schools*	*Score of the nonparticipating schools*	*Estimated ATT*	*ATT/mean score of untreated schools (percent)*
P5	178.52	174.95	1.13	0.644
P10	190.66	186.15	1.93	1.039
P20	206.92	201.45	3.04	1.509
P30	219.11	213.04	2.94	1.381
P40	229.79	223.37	2.74	1.227
P50	239.90	232.44	3.34	1.437
P60	250.14	241.80	4.21	1.741
P70	261.28	252.26	4.72	1.871
P80	274.44	264.88	5.11	1.928
P90	292.53	282.09	5.64	1.999
P95	306.94	295.71	5.95	2.013

Source: Authors' calculations.

a. Dependent variable: math score in 2007 of ninth-grade students in each percentile. Estimates of ATT are results of the doubly robust estimator. Controls are the characteristics of schools, districts, principals, teachers, and students, plus regional dummies. All estimates are significant at 5 percent, except that for the first percentile, which is significant at 10 percent.

Brasil but that it is present for all students. This fact is important, demonstrating that the OBMEP improves the average performance of schools and that the gain affects all students, not only the higher achievers.

OBMEP prizes are distributed for several categories of winners. Three thousand medals are distributed among the top students (300 gold, 900 silver, and 1,800 bronze), and they are equally divided between the three levels of the competition. In addition, up to 30,000 honor certificates are distributed to the next-best students. Considering all the categories, 9,775 schools in our sample had winning students in 2007, that is, 43 percent of the treated schools. Each of the winning schools had on average 2.75 winning students.

Is the impact of the OBMEP higher for schools with winners? If the mechanism through which the math olympics increases test scores has to do with competition and motivation, we would expect the effect to be stronger when a significant share of the students has a real chance of winning. Table 9 reports the results of our basic specifications, including an indicator for the schools with winning students. The results show that the impact of OBMEP is higher in the schools with winning students and statistically significant only in those schools. Moreover, the number of winners in each school is probably insufficient to drive a spurious correlation between participation in the OBMEP and the average test scores in Prova Brasil.

TABLE 9. Olympic Winners[a]

Schools	*Difference in means*	*ATT (level)*	*ATT (difference-in-differences)*
Participating in OBMEP 2007	1.20*	0.44	0.90
	(0.44)	(0.51)	(0.58)
With winning students	16.12*	3.86*	2.21*
	(0.23)	(0.45)	(0.35)
Number of schools	14,769		
Schools with winners	6,663.		
Schools without winners	8,106.		

Source: Authors' calculations.

a. Robust standard error in parentheses. Dependent variable: ninth-grader average math score in 2007 (level) and difference between 2007 and 2005 (difference-in-differences). Doubly robust estimator. Controls are the characteristics of schools, districts, principals, teachers, and students, plus regional dummies. Sample includes all schools in the original sample (table 3) and indicators for schools with winning students.

*Significant at 1 percent.

Additional Impact Estimates

Table 10 shows the impact of the OBMEP on other dependent variables. We find a significant impact on school promotion and dropout rates in 2007, but we find no impact on next-year enrollment or class sizes. We also investigate possible heterogeneous effects on the math scores among different

TABLE 10. Additional Results[a]

Dependent variable	*Average of dependent variable in the sample*	*Coefficient (ATT)*	*Robust standard error*
Promotion rate (grades 6–9)[b]	76.2	1.07**	(0.53)
Repetition rate (grades 6–9)[b]	14.3	−0.44	(0.38)
Dropout rate (grades 6–9)[b]	9.5	−0.63*	(0.36)
Enrollment (grades 8–9)[c]	180.8	−1.50	(4.69)
Class size (grades 6–9)[c]	31.2	−0.02	(0.25)
Heterogeneous effects: distribution of per capita municipal income[d]			
1st one-third ($15–$98)	228.9	1.71**	(0.85)
2nd one-third ($98–$166)	242.5	1.52*	(0.90)
3rd one-third ($166–$516)	246.5	2.71***	(0.74)
Heterogeneous effects: educational system (municipal or state schools)			
State schools	240.4	2.07***	(0.71)
Municipal schools	236.9	2.01***	(0.74)

Source: Authors' calculations.

a. Standard errors estimated by the Eicker-White procedure. All estimates are results of the doubly robust estimator. Controls are the characteristics of schools, districts, principals, teachers and students, plus regional dummies.

b. Average rates between grades 6 and 9 in 2007.

c. 2008 School Census data.

d. Computed at 2000 prices.

*Significant at 10 percent; **significant at 5 percent; ***significant at 1 percent.

municipalities (measured by per capita income) and different school administrations (state or local). The impact is stronger in richer municipalities, but no significant differences were found between state and municipal schools.

Analysis of the Economic Return

From the estimated impacts of the OBMEP on the math scores on the Prova Brasil of ninth-graders, we performed an analysis comparing the costs and benefits of the program over the students' lifetimes. The idea was to translate the effect found in the previous section into monetary benefits. Doing so required making some assumptions about how higher math scores can affect job earnings and constructing scenarios to compare additional earnings against the amounts invested in the program.

In 2007, 4.9 million students took part in the first phase of the OBMEP at level 2, of whom 9 percent participated only in 2007, 23 percent in one other year (2005 or 2006), and 69 percent in all three years. All of those students could have benefited from the OBMEP. To analyze the flow of benefits we used the following hypotheses and procedures:

—The estimated positive impact on the average score of ninth-graders holds in absolute values for all the students signed up for the first phase of the 2007 OBMEP. Since we know the separate impacts of the number of times that a student participated, we performed three calculations of the return.

—The expected monetary return from participation in the OBMEP was calculated from the improvement in performance, by number of times participating. A study with panel data in the United States shows that this relationship exists (Murnane and others 2000). There are no panel data available in Brazil to follow the same individuals, but Curi and Menezes-Filho (2007) evaluated whether the quality of learning measured in terms of math proficiency obtained on the SAEB (Basic Education Evaluation Test) among high school seniors of a particular generation affected the salaries of that cohort five years later. The authors showed that student performance on the evaluation test affected future salaries with an estimated elasticity of 0.3. According to those findings, the improved performance of the ninth-graders on the Prova Brasil should boost their future wage income with an estimated elasticity of 0.3.

—We assumed that the returns of education are constant over time. With data from the 2007 PNAD (National Household Survey), we projected the

TABLE 11. Economic Return of the OBMEP[a]

Scenario		Number of years of participation: Two	Three	Total
Scenario 1 (OBMEP)	Total NPV	R$116.7[b]	R$704.1[b]	R$820.8[b]
	NPV/student	R$115	R$202	R$169
	IRR/year (percent)	39	45	39
Scenario 2 (Prova Brasil)	Total NPV	R$86.2[b]	R$547.4[b]	R$633.6[b]
	NPV/student	R$85	R$157	R$130
	IRR/year (percent)	14	16	14

a. NPV = net present value; IRR = internal rate of return. We considered a discount rate of 5 percent a year to calculate the IRR.
b. Millions of reais (US$1 = R$2.19).

annual wage earnings of an 18-year-old with nine years of schooling when entering the job market until retirement at age 60.

From the estimated impact on student math scores according to the number of times that they participated in the OBMEP and with the performance-income elasticity, we calculated the expected variations in annual salaries. For one instance of participation (variation of 0.32 percent on the average of the treated students), we estimated an increase of 0.10 percent in future annual salary, with the percentage rising to 0.19 percent with two instances of participation and to 0.30 percent with three.

With respect to the costs of the OBMEP, we considered a figure of R$2 per student per year, as that is the figure reported by the OBMEP organizers. One other scenario considers the costs per student of the Prova Brasil 2007, whose structure is similar to OBMEP's: R$17 per student. We considered the costs to be proportional to the number of times that the schools participated in the OBMEP.

Table 11 presents the economic return of the program, broken down by number of times students participated, considering three cost scenarios. As school participation only in 2007 did not show a significant impact, we considered the future salary benefits only for students from schools that had participated previously.

In all cost scenarios, the program's return is positive and high, as we consider a risk-free discount rate of 5 percent a year. By calculating the overall average return, we obtained in scenario 2 a net present value per student of R$130 and an internal rate of return of 14 percent a year. That indicates that the OBMEP is a good investment in terms of public policy because the per-student costs are very low and the number of beneficiaries is very high.

According to this impact evaluation, the OBMEP has a positive influence on the quality of public school education, increasing the average math score of the treated schools in national educational assessments. That result becomes more pronounced as the number of times that a school participates increases and for students with better school performance. Our calculation of the economic return shows that the OBMEP has a high rate of return and will generate future earnings benefits for the participants, without considering other possible positive externalities for the students and for society in general.

Conclusion

We carried out an economic evaluation of the Brazilian Public School Math Olympics, a program promoted since 2005 by the Institute of Pure and Applied Mathematics in partnership with the Ministry of Education and the Ministry of Science and Technology. One of the program's aims is to encourage the study of mathematics in public schools and to increase the quality of public education.

Each year since its inception the OBMEP has attracted an increasing number of participants from schools and students in the sixth through twelfth grades. In 2010 more than 19 million students participated. It is currently considered the leading school academic competition in the country. To see whether it is living up to its goals, we evaluated the impact of schools' participation in the 2007 OBMEP on the average math scores of ninth-graders on the 2007 Prova Brasil.

We used a two-step estimation, combining linear regression with propensity score weighting. The resulting estimator is asymptotically more efficient than other methods based on this estimated probability and thus is considered doubly robust. We showed that the OBMEP has a positive and statistically significant effect on the average math scores of ninth-graders on the Prova Brasil (2007). That impact rises as the number of times that a school participates in the program increases, and it is greater in the higher student score percentiles, although all percentiles benefit. We also show a positive effect on reading test scores, suggesting that at the currently low levels of educational quality, students' motivation to succeed in the OBMEP spread to other subjects.

The analysis of the economic return brought positive results, showing that the OBMEP, by enhancing the quality of public school education in the country, will generate future gains in earnings of the participants and that it is cost-effective.

Appendix

TABLE A. Profile of Schools Participating in the OBMEP

	Participants	Nonparticipants	*Difference of means test* T statistic before balancing	T statistic after balancing[a]
Information from the Prova Brasil				
Score, ninth-grade math 2005	239.7	233.1	−12.15	. . .
Score, ninth-grade math 2007	239.8	231.7	−17.25	. . .
Score, ninth-grade Portuguese, 2005	224.4	220.8	−7.35	. . .
Score, ninth-grade Portuguese, 2007	227.8	222.4	−12.68	. . .
Percent of principals . . .				
who have a postgraduate degree	71.2	62.5	−7.53	−0.53
who have 11 to 15 years as head of the school	4.7	6.9	4.00	−1.12
who have more than 15 years as head of the school	3.2	4.1	2.07	0.35
who are between the ages of 30 and 39	24.1	22.0	−1.97	−0.63
who were chosen by a competitive exam or election process	17.5	13.4	−4.20	0.35
Percent of schools . . .				
that receive state government funding	68.0	58.1	−7.44	0.35
that have a student entry test	0.8	1.0	1.12	0.17
that have high staff turnover	38.7	32.9	−4.67	−1.06
that have had interruption in school activities	19.0	20.8	1.81	0.44
Percent of ninth-grade students . . .				
who started with preschool	81.7	78.1	−10.02	−0.33
who are boys	45.7	46.0	0.86	0.85
whose parents attend parent-teacher meetings	91.6	89.1	−13.63	−1.88
who have at least one parent who completed high school	7.4	5.2	−12.71	−0.37
who are white	1.7	1.7	7.94	1.18
Average number of cars owned by students' households	35.7	34.2	−2.96	−0.21
Average eighth-grade enrollment in students' schools	92.7	63.2	−18.09	−1.64
Percent of municipal schools (as opposed to state schools)	35.0	44.6	8.16	−1.21
2006 School Census				
Average number of teachers in grades 1–9	28.2	26.0	−6.40	0.01
Percent of schools with Internet access	57.0	44.5	−10.25	1.17
Percent of schools that have computers for use by grades 8 and 9	39.0	25.5	−11.21	0.79
Percent of teachers with college diplomas	88.3	84.6	−6.73	−1.69
Percent of schools with a "cycle system"[b]	36.7	32.2	−3.74	1.76
Average class size in grade 9	32.3	30.2	−9.45	−0.28
Average number of hours in the ninth-grade school day	4.4	4.3	−10.92	0.19
2000 Demographic Census				
Average population of the municipalities	635,183	1,414,768	15.57	−1.26
Average per capita income of the municipalities (R$)	263.4	311.8	12.31	−1.73

Sources: For "Information from the Prova Brasil" and "2006 School Census," INEP/MEC (2010); for "2000 Demographic Census," IBGE (2000).

a. For the balancing test, we divided the sample into four p-score strata to provide the statistics for the first quartile, with the results for the other quartiles following the same scheme.

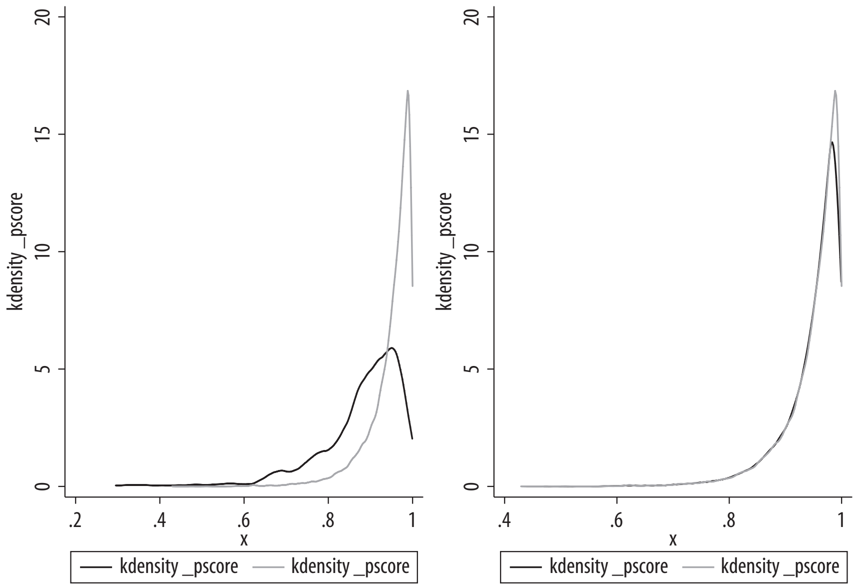
b. A system in which schooling is organized into cycles lasting two to four years and students can be held back only one year at the end of a cycle.

TABLE B. Logit Estimate: Decision of Schools to Participate in the OBMEP

Dependent variable = participation in OBMEP in 2007	*Coefficient*	*Standard error*	*z*	*P > z*
Dummy, midwest region	−1.02	0.18	−5.58	0.000
Dummy, southeast region	−1.47	0.15	−10.03	0.000
Dummy, south region	−2.29	0.20	−11.31	0.000
Municipal school	0.16	0.14	1.15	0.250
Number of teachers in grades 1–8	0.03	0.00	7.94	0.000
School has Internet access	0.46	0.09	4.90	0.000
Use of computers by students	0.20	0.09	2.12	0.034
School with cycle system	0.55	0.14	4.04	0.000
Cycle x municipal school (iteration)	−0.83	0.18	−4.61	0.000
Share of teachers with college degrees (squared)	0.63	0.15	4.20	0.000
Average hours in school day	0.21	0.12	1.80	0.072
Score on 2005 Prova Brasil eighth-grade math test	0.03	0.00	9.54	0.000
Log, municipal population	−0.37	0.04	−9.85	0.000
Log, per capita municipal income	0.18	0.14	1.27	0.203
Percent of principals with postgraduate degrees	0.36	0.08	4.31	0.000
Percent of schools with high staff turnover	0.11	0.08	1.40	0.161
Percent of schools with interruption in school activities	−0.13	0.10	−1.36	0.175
Age of principal (between 30 and 39)	0.19	0.10	1.99	0.047
Time of principal as head of school (more than 10 years)	−0.41	0.14	−2.88	0.004
Principal chosen by competitive exam or election	0.27	0.12	2.31	0.021
School has student entrance exam	−0.85	0.39	−2.20	0.028
School receives state government funding	0.23	0.11	2.17	0.030
Percent of white students	0.11	0.34	0.32	0.752
Percent of parents who attend parent-teacher meetings	2.00	0.48	4.21	0.000
Percent of students whose parents have a car	−1.58	0.42	−3.72	0.000
Percent of students who started with preschool	−0.19	0.31	−0.61	0.544
Percent of boys	−0.03	0.42	−0.07	0.945
Percent of students whose parents completed high-school	1.24	0.71	1.75	0.079
Constant	−1.87	1.41	−1.32	0.185
Pseudo R^2	0.1287			
Number of observations	14,778			

Source: Authors' calculations.

FIGURE A. Quality of Matching (Nearest Neighbor): Density Kernel of the Probability of Treatment before and after Matching



Source: Authors' calculations.

TABLE C. Difference-in Differences: OLS Regression Weighted by the Propensity Score (Doubly Robust)

Dependent variable = (score 2007 − score 2005)	*Coefficient*	*Robust standard error*	*T statistic*	*P > t*
Participated in 2007 OBMEP	1.91	0.58	3.32	0.001
Dummy, midwest region	−0.71	0.97	−0.73	0.467
Dummy, southeast region	−0.33	1.19	−0.28	0.781
Dummy, south region	−1.93	1.14	−1.69	0.091
Municipal school	0.04	0.91	0.04	0.969
Number of teachers in grades 1–8	0.03	0.03	1.00	0.317
School has Internet access	0.00	0.66	−0.01	0.994
Use of computers by students	−0.36	0.68	−0.52	0.600
School has cycle system	2.24	0.88	2.55	0.011
Cycle x municipal school (iteration)	−1.15	1.43	−0.81	0.419
Share of teachers with college degrees (squared)	−0.96	1.18	−0.81	0.417
Average hours in school day	−1.08	0.75	−1.43	0.153
Log, municipal population	−0.75	0.23	−3.31	0.001
Log, per capita municipal income	1.45	0.86	1.69	0.092
Percent of principals with postgraduate degrees	0.51	0.57	0.89	0.371
Percent of schools with high staff turnover	0.15	0.59	0.25	0.801
Percent of schools with interruption in school activities	−1.56	0.65	−2.40	0.016
Age of principal (between 30 and 39)	−1.03	0.76	−1.35	0.178
Time of principal as head of school (more than 10 years)	−2.06	1.04	−1.99	0.047
Principal chosen by competitive exam or election	0.20	0.92	0.21	0.832
School has student entrance exam	8.23	4.16	1.98	0.048
School received state government funding	0.22	0.81	0.27	0.787
Percent of students				
who are white	0.03	3.50	0.01	0.992
who are boys	9.49	2.91	3.26	0.001
who live with both their parents	6.42	2.46	2.61	0.009
who started in preschool	7.81	3.88	2.02	0.044
who work	−17.22	2.70	−6.37	0.000
who have a washing machine at home	−4.89	3.14	−1.55	0.120
whose parent/s (at least one) completed high school	7.96	5.27	1.51	0.131
who did not respond to question on mother's level of schooling	−1.90	2.18	−0.87	0.383
who have Internet access at home	−8.01	4.29	−1.87	0.062
Constant	3.78	4.21	0.90	0.369
R^2	0.0718			
Number of observations	14,776			

Source: Authors' calculations.