

# **Empirical Essays on the Economics of Education**

Anne Caroline Costa Resende

Department of Economics

Royal Holloway, University of London

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## **Declaration of Authorship**

I Anne Caroline Costa Resende hereby declare that this thesis and the work presented in it is entirely my own. Where I have consulted the work of others, this is always clearly stated.

Signed: Anne Caroline Costa Resende

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## Abstract

This thesis addresses issues that do not have a clear cut consensus in the economics of education literature.

We begin by trying to identify regions of returns to schooling in the UK using an approach developed in Manski (1997) and Manski and Pepper (2000). Non-parametric bound analysis has the advantage to rely on relatively weak and somewhat testable assumptions. Applying this approach on two different large data sets we establish an identification region for the return to education and compare the results with some traditional parametric approaches commonly employed in the literature. The estimates show that the returns to education computed through weaker assumptions are smaller than (and in some cases well below) some of the point estimates usually reported in the literature.

In the second part of this study, we investigate the effects of a funding education reform implemented in Brazil in 1998 (FUNDEF/FUNDEB), which largely increased educational expenditures across the country. The identification strategy comes from the fact that the exposure and intensity of the reform varied across municipalities and years. First, we analyse whether the redistributive effect of the reform reduce inequality in terms of schools resources between poor and rich regions. Second, we verify whether an increase in the availability of resources to schools brought by the reform translated into higher students' performance. The results suggest a decrease in the inequality of school resources within and to some extent across regions. However, there is no evidence of effects on students' test scores. We also assess the effects of the funding reform on somewhat long term student's outcomes. The results suggest that the reform leads to an increase in education attainment for individuals who went to schools in the most affected regions.

## Table of Contents

|  |    |
|--|----|
| Chapter 1: Introduction .....  | 11 |
| Chapter 2. Leaps and Bounds: What can we Learn about the Rate of Return to Education in the UK from Partial Identification?..... | 15 |
| 2.1. Introduction .....  | 15 |
| 2.2 Some Parametric Approaches .....   | 16 |
| 2.3 Partial Identification Bounds: Empirical Framework .....   | 21 |
| 2.3.1 The No-assumption Bounds .....   | 22 |
| 2.3.2 Identification Assumptions .....   | 22 |
| 2.3.2.1 Monotone Treatment Response (MTR) .....  | 23 |
| 2.3.2.2 Monotone Treatment Selection (MTS) .....   | 23 |
| 2.3.2.3 Monotone Instrumental Variable (MIV) .....   | 25 |
| 2.3.2.4 MTR&MTS and MIV .....  | 25 |
| 2.4. Review of some Empirical Evidence for the UK .....  | 26 |
| 2.5. Results .....   | 29 |
| 2.5.1 NCDS .....   | 29 |
| 2.5.2 General Household Survey (GHS) .....   | 35 |
| 2.6. Comparing Partial Identification Bounds to Others Identification Approaches .....   | 36 |
| 2.7 Summary and Conclusions .....  | 38 |
| Chapter 3: The short and long term effects of an Educational Funding Reform on Regional Inequality in Brazil.....                | 54 |
| 3.1 Introduction .....   | 54 |
| 3.2 The FUNDEF Program .....   | 57 |
| 3.3 Literature Review .....  | 60 |
| 3.4 Backgrounds of the Brazilian Educational System .....  | 65 |
| 3.5 Empirical Strategy.....  | 67 |

|                                       |     |
|---------------------------------------|-----|
| 3.5.1 The Identification Problem..... | 71  |
| 3.6 Data .....                        | 75  |
| 3.7 Results .....                     | 78  |
| 3.7.1 School Inputs.....              | 78  |
| 3.7.2 Student's Test Scores .....     | 84  |
| 3.7.3 Education Attainment.....       | 85  |
| 3.8 Conclusions .....                 | 87  |
| APPENDICES.....                       | 125 |
| Chapter 4: Conclusion.....            | 126 |
| References .....                      | 129 |

## List of Tables

|   |    |
|---|----|
| Table 2.1: Mean (log) wages by qualification levels - NCDS by ages - Men .....                                      | 40 |
| Table 2.2: Mean (log) wages by Math Ability at 11 - NCDS - Men .....  | 40 |
| Table 2.3: Mean (log) wages by Reading Ability at 11 - NCDS – Men .....   | 41 |
| Table 2.4: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications - NCDS 42 years – Men .....    | 42 |
| Table 2.5: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications - NCDS 33 years – Men .....    | 43 |
| Table 2.6: Mean (log) wages by qualification levels - NCDS by ages – Women .....                                    | 43 |
| Table 2.7: Mean (log) wages by Math Ability at 11 - NCDS - Women .....  | 44 |
| Table 2.8: Mean (log) wages by Reading Ability at 11 - NCDS –Women.....   | 44 |
| Table 2.9: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications – NCDS 42 years – Women .....  | 45 |
| Table 2.10: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications – NCDS 33 years – Women ..... | 46 |
| Table 2.11: Mean (log) wages by schooling levels by gender – GHS .....  | 46 |
| Table 2.12: Mean (log) wages by SLA-MIV variable - GHS .....  | 47 |
| Table 2.13: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications - GHS – Men.....              | 47 |
| Table 2.14: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications - GHS –Women.....             | 48 |
| Table 2.15: Returns to Schooling Using Change in SLA an (M)IV .....   | 49 |
| Table 3.1: Average Years of Schooling for the Adult Population, 1960-2010.....                                      | 90 |
| Table 3.2: Descriptive Statistics - School Census.....  | 91 |
| Table 3.3: Summary Statistics - School Census.....  | 92 |
| Table 3.3 (continued): Summary Statistics - School Census .....   | 93 |

|  |     |
|--|-----|
| Table 3.4: Descriptive statistics: Prova Brasil and Census 2010 - 8 <sup>th</sup> grade .....                    | 94  |
| Table 3.5: Summary Statistics – PNAD (1992-2011).....  | 95  |
| Table 3.6b: IV First Stage Results - Schools Inputs .....  | 97  |
| Table 3.6c: IV First Stage Results - Schools Inputs.....   | 98  |
| Table 3.7a: OLS and IV Results: Education Spending per capita .....  | 99  |
| Table 3.7b: Minimum expending levels transfers.....  | 100 |
| Table 3.8a: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index - Centre-West.....          | 101 |
| Table 3.8b: OLS and IV Results: Proportion of Teachers with a Degree - Centre-West.....                          | 102 |
| Table 3.8c: OLS and IV Results: Pupil Teacher Ratio - Centre-West.....   | 103 |
| Table 3.9a: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index - South .....               | 104 |
| Table 3.9b: OLS and IV Results: Proportion of Teachers with a Degree - South .....                               | 105 |
| Table 3.9c: OLS and IV Results: Pupil teacher ratio - South .....  | 106 |
| Table 3.10a: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index – Southeast .....          | 107 |
| Table 3.10b: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index – Southeast .....          | 108 |
| Table 3.10c: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index – Southeast .....          | 109 |
| Table 3.11a: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index – North and Northeast..... | 110 |
| Table 3.11b: OLS and IV Results: Pupil Teacher Ratio – North and Northeast.....                                  | 111 |
| Table 3.11c: OLS and IV Results: Pupil Teacher Ratio – North and Northeast.....                                  | 112 |
| Table 3.12: IV First Stage Results – Math Test Scores 8 <sup>th</sup> grade .....                                | 113 |
| Table 3.13a: OLS and IV Results - Student’ test scores 8 <sup>th</sup> grade .....                               | 114 |

|  |     |
|--|-----|
| Table 3.13b: OLS and IV Results - Student' test scores 8 <sup>th</sup> grade.....              | 114 |
| Table 3.13c: OLS and IV Results - Student' test scores 8 <sup>th</sup> grade .....             | 115 |
| Table 3.14: IV First Stage Results – Educational Attainment .....                              | 116 |
| Table 3.15: OLS and IV Results: Educational Attainment Outcomes.....                           | 117 |
| Table A.1: Percentage of enrolment considered in each education level - FUNDEF/FUNDEB<br>..... | 125 |
| Table A.2: Weighing factor - FUNDEF/FUNDEB.....  | 125 |



## List of Figures

|   |     |
|---|-----|
| Figure 2.1: Wages as a function of Qualifications levels: bounds and ETS point estimates – NCDS Men 42 years old .....  | 50  |
| Figure 2.2: Wages as a function of Qualifications levels: bounds and ETS point estimates – NCDS Women 42 years old .....  | 51  |
| Figure 2.3: Wages as a function of Qualifications levels: bounds for (A-level, HE) – NCDS Men 42 years old .....  | 52  |
| Figure 2.4: Wages as a function of Qualifications levels: bounds for (A-level, HE) – NCDS Women 42 years old.....   | 53  |
| Figure 3.1: Education Expenditures per pupil as Share of GDP per capita .....   | 118 |
| Figure 3.2 Municipal Spending on Education as a Share of municipal GDP - by regions   | 118 |
| Figure 3.3 Municipal Expenditure per Pupil by regions (Constant 2011 R\$).....  | 119 |
| Figure 3.4 Real Spending on Education per Pupil - Municipalities in the top quartile of GDP per capita .....  | 119 |
| Figure 3.5 Real Spending on Education per Pupil - Municipalities in the bottom quartile of GDP per capita .....   | 120 |
| Figure 3.6 Net and Gross enrolment rate - Primary Education .....   | 120 |
| Figure 3.7: Percentage of students performing below proficiency Level 2 in reading in 2000 and 2009 .....   | 121 |
| Figure 3.8: Percentage of students performing below proficiency Level 2 in mathematics 2003 and 2009 .....  | 121 |
| Figure 3.9: Intensity of FUNDEF reform on municipalities by regions (1998-2010) ..  | 122 |
| Figure 3.10: Intensity of FUNDEF reform on municipalities by percentiles (1 <sup>st</sup> , 2 <sup>nd</sup> , 3 <sup>rd</sup> , and 4 <sup>th</sup> ) of income per capita (1998-2010)..... | 123 |
| Figure 3.11: Enrolment rate Municipal and State schools (1,000s) .....  | 124 |

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Remaining errors are my own.

## Chapter 1: Introduction

According to Barro (1996), economic growth rate is positively related to schooling. In the OECD area, one additional year of education is estimated to increase economic output by 3 to 6% (OECD, 2005). Improving educational achievement is a policy priority in most countries, with policymakers looking for greater effectiveness and efficiency in the education system.

As pointed out by Card (1999), education plays a central role in modern labour markets. However, despite the extensive availability of data on individual's schooling and income, the literature has not yet reach a consensus on the magnitude of the causal effect of education on earnings. In fact the literature reveals a large range of estimates (Blundell *et al*, 2005). Besides, some studies - Belzil and Hansen (2002) and Manski and Pepper (2000) – have casted doubt on the validity of most results reported in the empirical literature of returns to education. The crucial critic is that these estimates usually rely on stronger and questionable assumptions. Generally assuming a linear and homogenous relationship between wages and schooling and in some cases an exogenous treatment selection, which states that schooling is unrelated to unobserved factors affecting wages

Therefore, the objective of the second chapter of this study is to identify regions of returns to schooling in the UK using a different approach. We use a methodology developed in Manski (1997) and Manski and Pepper (2000) and used, in the context of returns to education, in Okumura and Usiu (2010) and Giustinelli (2011). Non-parametric bound analysis has the advantage to rely on relatively weak and somewhat testable assumptions. By applying this approach to two large British data sets - the National Child Development Survey (NCDS) and the General Household Survey (GHS) -, we intend to establish an identification region for the return to education. The analysis benefits not only from the vast information on education in each survey but also from the comparison of the results among data sets and with estimates obtained using conventional methods.

A great deal of attention has been devoted to the quantity of schooling.<sup>1</sup> Studies that focused on the economic returns to different levels of school attainment have shown that more schooling is associated with higher individual earnings. However, besides expanding school

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<sup>1</sup> Card (1999), Harmon, Oosterbeek and Walker (2000).

attainment, the quality of education is also an important input. Barro (2002) shows that besides the quantity of schooling - measured by average years of schooling attainment - the quality of schooling - measured by test scores - also have a particularly positive relation with economic growth. Hanushek and Wößmann (2007) also shows that there is strong evidence that the cognitive skills of the population are related to individual earnings and economic growth.

Despite the significant increase in spending per per pupil over the past decade, many countries have not been able to improve the quality of learning outcomes (OECD, 2010). The development of educational systems towards access improvement, quality enhancement and increase performance in a cost-effective way is not a simple task. Governments must establish which policy choices promote efficient learning by taking into consideration their countries' specific contexts and realities.

In the last decades, the investment in education in Brazil has largely focused on increasing primary and secondary school enrolment rates, with the final goal of increasing the levels of education achievement. More recently, however, the quality of education has become a serious concern. One could argue that the development of cognitive abilities provided by the educational process depends both on the quantity and on the quality of the educational inputs received.

Too little is known about how effective public expenditures on education are at increasing pupil's performance and attainment. There is a large and controversial literature analysing the relationship between education expenditures and student's achievement, both in developing and developed countries (Glewwe *et. al* (2011), Hanushek (2006), Hanushek and Wößmann (2011), Gibbons *et. all* (2012), Holmlund *et. all* (2011)). The key question, therefore, is whether higher spending translates into student achievements. Identifying the effects of a higher per pupil spending on students' education performance is crucial since it is directly related to the formulation of efficient public policies within the realm of limited resources.

In 1998, Brazil implemented an education funding reform called FUNDEF (Fundo de Manutenção e Desenvolvimento do Ensino Fundamental e Valorização do Magistério). The reform only incorporated primary education at first. In 2007, the policy continued under the name FUNDEB (Fundo de Manutenção e Desenvolvimento da Educação Básica e de

Valorização dos Profissionais da Educação) and incorporated other levels of the educational system, such as the pre-school education and the secondary education. The reform changed the structure of public education funding and led to a large increase in spending per pupil. One of the major goals of the FUNDEF/FUNDEB reform was to reduce the large funding disparities across the country, with the ultimate goal of reducing inequalities in terms of students' achievements. The reform also aims at improving school quality by improving school inputs. The program is one of the major educational reforms implemented in the country. After the implementation of the FUNDEF, Brazil experienced a large increase in its educational expenditures.

Thus, in the third chapter we analyse the effects of FUNDEF reform on school inputs and students' outcomes. First, we analyse whether the redistributive effect of the Brazilian educational reform reduced inequality in terms of schools' resources between poor and rich regions. We also verify whether the increase in the availability of resources to schools brought by the reform translated into higher students' performance. The regional approach, not yet explored, should be the subject of an extensive discussion since education disparities are one of the major causes of the large income inequalities across the country (Reis and Paes de Barros (1990)). The measurement of the reform effects across largely different regions is crucial to identify the policy strengths and weaknesses when applied in different local realities. Another important aspect of the reform is its long-term effect. We also evaluate the effects of the reform on somewhat longer-term outcomes such as the probability to complete educational cycles and completed years of schooling. The identification strategy comes from the fact that the exposure and intensity of the reform varied across municipalities and years. We thus explore this variation across space and time to estimate the policy effects on education attainment. As far as we are aware, the majority of studies so far have mainly focused on FUNDEB short-term effects. This study, therefore, aims at covering this gap in the literature.

The thesis is organized as follows. Apart from this introduction, chapter 2 tries to establish an identification region for the return to education in the UK using Manski (1997) and Manski and Pepper (2000) non-parametric bounds. Chapter 3 evaluates the effects of an educational funding reform implemented in Brazil on several school inputs. We also assess whether an increase in the availability of resources to schools brought by the reform translated

into higher students' performance. Lastly, the impact of the reform on somewhat long term effects are also estimated. Chapter 4 concludes.

## **Chapter 2. Leaps and Bounds: What can we Learn about the Rate of Return to Education in the UK from Partial Identification?**

### **2.1. Introduction**

According to Becker (1964) the most important determinant of the amount invested in human capital is its profitability or rate of return; i.e. individuals invest in their own education in order to capture these returns. As such a great amount of research has focused on estimating the returns to education. However, despite extensive availability of data on individual's schooling and income the literature reveals a large range of estimates (Blundell *et al*, 2005). Besides, some studies - Belzil and Hansen (2002), Okumura and Usui (2010) and Manski and Pepper (2000) – have casted doubt on the validity of most results reported in the empirical literature of returns to education, and advocated estimating regions of returns rather than point estimates.

The literature on returns to education is largely based on Ordinary Least Squares (OLS) and attempt to identify point estimates of the returns. To do so it assumes a linear and homogenous relationship between the response function and the treatment variable, i.e., that all individuals in the population experience the same return per year of schooling and that each additional year of schooling has the same marginal return.<sup>2</sup> In addition, it assumes exogenous treatment selection which states that schooling are unrelated to unobserved factors affecting wages. While it is possible to relax this assumption by relying on instrumental variables, regression discontinuity or family fixed effects (twin), these methods all impose additional identifying assumptions, we instead identify bounds in which return to education lies. We use an approach developed in Manski (1997) and Manski and Pepper (2000). The crucial idea of non-parametric bounds is that, instead of obtaining points estimates, which usually relies on stronger and questionable assumptions, the method calculates bounds for the treatment effects based on weaker and more credible hypothesis.

Non-parametric bounds on partially identified parameters were first introduced by Manski (1990) and further developed in Manski (1995, 1997) and Manski and Pepper (2000). Manski and Pepper (2000) and Okumura and Usiu (2010) applied bounds on returns to

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<sup>2</sup> In the multiple-treatment model different schooling levels are allowed to have different effects on wages even though the returns to a given level are homogenous across individuals.

schooling from a sample taken from the National Longitudinal Survey of Youth (NLSY) for the U.S. Some of their estimated upper bounds are lower than the point estimates reported in the literature. The authors found that the difference on the returns to schooling between high school and college is at most 0.257. Thus, the yearly average treatment effect is at most 0.064, which falls in the lower range of the point estimates on the returns to schooling reported by Card (1999) for the U.S (0.052 to 0.132), which Manski and Pepper (2000) interpret as indication of misspecification of the parametric model (e.g. due to the linearity assumptions). This chapter implements non-parametric bounds to estimate returns to education in the UK. We compute estimates for two large British data sets, and compare them with some parametric estimates.

Non-parametric bounds, however, also present some drawbacks. Firstly, bounds can be very large and uninformative unless more assumptions are imposed. Secondly, the literature for partially identified parameter has not yet reached a formal consensus on which method yields the most credible confidence interval for the bound estimates. Thirdly, the validity of the assumptions can also be questioned.

The chapter is organized as follows. In section 2.2, we review the econometrics behind the various estimation strategy commonly used to estimate returns to education. Section 2.3 presents the literature review. Empirical results are shown in section 2.4. Section 2.5 compares non-parametric bounds to the results using other identification approaches. Section 2.6 concludes.

## **2.2 Some Parametric Approaches**

The causal relation between schooling and earnings can be defined as the relation which describes what would be a given individual earnings if he or she obtained certain levels of education. In our setting, the realized outcome  $Y_i \equiv Y_i(S_i)$  is the level of earnings for an individual  $i$  who receives treatment  $S_i$ , i.e  $S_i$  represents the realized years of schooling, both of which are observed.

To begin with suppose schooling is a binary decision like go or not to college. To describe the problem more precisely, the treatment status is described by a binary random variable,  $S_i = (0,1)$ . The treated individuals are the ones who actually choose to go college,  $S_i = 1$ , and the control group are the ones who choose not to go,  $S_i = 0$ . Let  $Y_{i}$  be



the potential outcome for individual  $i$  if  $S_i = 1$ , and  $Y_{0i}$ , the potential outcome for  $i$  if  $S_i = 0$ .

The observed outcome,  $Y_i$ , can be written in terms of potential outcomes as:

$$Y_i = Y_{0i} + (Y_{1i} - Y_{0i})S_i \quad (1)$$

Comparing the average outcome of those who were and were not treated, we get:

$$\begin{aligned} E[Y_i | S_i = 1] - E[Y_i | S_i = 0] &= E[Y_{1i} | S_i = 1] - E[Y_{0i} | S_i = 1] \\ &+ E[Y_{0i} | S_i = 1] - E[Y_{0i} | S_i = 0] \end{aligned} \quad (2)$$

where the first term on the right hand side is called the average treatment effect on the treated (ATT).

The problem is that the counterfactual outcome of an individual under treatment  $E[Y_{0i} | S_i = 1]$  cannot be observed, since an individual may only be observed as having gone or not gone to college, but not in both states at a specific point in time. One way to compute the ATT is to replace the average outcome of the treated individuals if they would have not been treated, with the average results of the individuals who had not been treated  $E[Y_{0i} | S_i = 0]$ . However replacing the unobserved earnings of the treated by the observed earnings of the non-treated introduce some bias, since it is unlikely that  $E[Y_{0i} | S_i = 1] = E[Y_{0i} | S_i = 0]$ . The bias arises due to differences in the observable and unobservable attributes between treatment and control groups; i.e. individual who chose to go to college are different from those who decided not to go, and those differences are correlated with their earning potentials. For example, more motivated individuals are more likely both to go to college and to earn higher wages.

The bias problem disappears with random assignment of the individuals between groups. If we could allocate individuals' schooling randomly, those with different levels of schooling would be on average identical. Random assignment of  $S_i$  solves the selection problem as it makes  $S_i$  independent of potential outcomes. The independence of  $Y_{0i}$  of  $S_i$  makes  $E[Y_{0i} | S_i = 1] = E[Y_{0i} | S_i = 0]$ ; i.e. the selection bias disappears.

If the selection process in turn is based on observable characteristics the selection bias can also disappear. Conditioning on  $X$ , a vector of observable variables, ATT can now be rewrite as:

$$E[Y_{1i} - Y_{0i} | S_i = 1, X] = E[Y_{1i} | S_i = 1, X] - E[Y_{0i} | S_i = 1, X] \quad (3)$$

which means that

$$Y_{0i}, Y_{1i} \perp S_i | X_i \rightarrow E[Y_{0i} | X_i, S_i = 1] = E[Y_{0i} | X_i, S_i = 0] \quad (4)$$

$S_i$  is now independent of potential earnings given the observable characteristics  $X$  – this is known as the Conditional Independence Assumption (CIA). The CIA asserts that conditional on observed characteristics the selection bias disappears, so comparisons of average earnings across schooling levels have a causal interpretation.

We might be interested not only on the ATT,  $E[Y_{1i} - Y_{0i} | S_i = 1]$ , but also on the average treatment effect (ATE),  $E[Y_{1i} - Y_{0i}]$ . The average causal effect of a one year increase in schooling given CIA is:

$$E[Y_i | X_i, S_i = s] - E[Y_i | X_i, S_i = s - 1] = E[Y_i(s) - Y_i(s - 1) | X_i] \quad (5)$$

In the absence of an experiment, researchers rely on a variety of econometrics strategies to deal with the selection bias. Some of the statistical techniques employed in the context of returns to schooling include regression, matching, instrumental variables, regression discontinuity, family fixed effects (twins).

Consider the following equation:

$$Y_i = \alpha_i + \beta S_i + \delta X_i + \varepsilon_i \quad (6)$$

This regression presents a linear relationship between years of schooling and earnings and a constant return to education, hypothesis commonly imposed in the literature. Given that CIA holds for the vector of observed covariates,  $X_i$ , the regression coefficient  $\beta$  is the causal effect of interest. The key assumption here is that the observable characteristics,  $X_i$ , are the only reason why  $\varepsilon_i$  and  $S_i$  are correlated. This is similar to the exogenous treatment selection (ETS) assumption commonly imposed on OLS. On that case given  $X$ , the selection into treatment is exogenous and schooling is unrelated to unobserved factors affecting wages.

Matching in turn, estimate the treatment effects by comparing (matching) individuals with the same covariates. Under the matching assumption, all the relevant differences between treated and non-treated individuals are captured by their observable characteristics.

So according to the *selection on observables* assumption the outcomes are independent from the treatment given the observed attributes. Like regression, matching also assumes the CIA assumption. Unlike regression though matching does not impose linearity or a homogeneous additive treatment effect, but both methods depend heavily on the crucial assumption of the selection on observables.

The CIA required for regression and matching to identify treatment effects is a somewhat strong hypothesis as many of the necessary control variables are typically unmeasured or simply unknown. Instrumental Variable regressions (IV) methods yield robust estimations when the assumption of *selection on observable* is rejected.

If  $S_i$  is correlated with  $\varepsilon_i$ , regression estimates of (6) do not estimate  $\beta$  consistently. Now suppose there exist a variable  $Z_i$ , which is correlated with  $S_i$ , but unrelated to  $Y_i$ . It therefore follows that

$$Cov[Z_i, \varepsilon_i] = 0 \tag{7}$$

which is called the *exclusion restriction* since  $Z_i$  can be said to be excluded from the causal model of interest. A variable  $Z_i$  is an instrument for the causal effect of  $S_i$  on  $Y_i$  if it is correlated with the endogenous variables  $S_i$  and does not appear as a regressor in the model for  $Y_i$ . In the returns to education literature several instruments have been used as.

In the literature on returns to education, the instruments used vary from changes in compulsory schooling laws, to variation in tuition fees, birth order, distance to college and others.<sup>3</sup> Whether an IV approach can be used to identify the causal effect of years of schooling on earnings depends on the strength and validity of the instruments employed. Weak instruments, that is, instruments that are only weakly correlated with the included endogenous variables, tend to produce biased results even in large samples (Baker *et al*, 1995). Another potential problem is that different instruments estimate different local average treatment effects (LATE) and not the average treatment effect for the population. LATE will typically vary depending on which instrument is used; i.e. different instruments rely on subpopulations that might have different characteristics from the overall population. These

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<sup>3</sup> Card (1999).

estimates will only estimate the average treatment effect if the earnings schooling function is linear and homogeneous.

An alternative identifying strategy is to rely on dataset containing twins.<sup>4</sup> This method deals with selection bias by applying the so called within-twin pair estimator; i.e. it assumes that unobservable characteristics of identical twins are identical, and thus get eliminated with differentiating within twin pair. Returns to schooling are estimate comparing the difference in twins' education with the difference in their earnings. However whilst within-pair differencing removes some of the bias, there might be other differences between twins that are unobservable to the researcher and that affect both schooling decision and wages.

$$Y_{1f} = \alpha_{1f} + \beta S_{1f} + A_{1f} + \varepsilon_{1f} \quad (8)$$

$$Y_{2f} = \alpha_{2f} + \beta S_{2f} + A_{2f} + \varepsilon_{2f} \quad (9)$$

where  $Y_{1f}$  is earnings for the first twin in family  $f$  and  $A_{1f}$  is all the other effects on wages apart from schooling.

A within-twin pair estimator for identical twins is given by:

$$Y_{1f} - Y_{2f} = \beta(S_{1f} - S_{2f}) + (A_{1f} - A_{2f}) + (\varepsilon_{1f} - \varepsilon_{2f}) \quad (10)$$

The assumption implied to get unbiased estimates with this strategy is that the difference in schooling between twins is random.

Regression discontinuities designs (RDD) have also been employed on the estimates of returns to education.<sup>5</sup> This method exploits discontinuity in rules that determine the treatment status, for example base on birth dates, some individuals are affected by a schooling reforms and others are not. There are two types of RDD designs, the so called fuzzy and sharp designs.

Consider the following example:

$$S_i = \begin{cases} 1 & \text{if } x_i \geq x_0 \\ 0 & \text{if } x_i < x_0 \end{cases}$$

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<sup>4</sup> Ashenfelter and Rouse (1998), Ashenfelter and Krueger (1994); Bonjour et. all (2003), Miller et. all (1995).

<sup>55</sup> Devereux and Hart (2010), Grenet (2009).

The treatment status,  $S_i$ , is a deterministic and discontinuous function of a covariate,  $x_i$ . It is a deterministic function because the value of  $S_i$  is based on the  $x_i$  values and a discontinuous function because treatment changes exactly on the point where  $x_i = x_0$ . The sharp design can also be thought as a selection-on-observables approach, but it assumes that close to the discontinuity the populations are identical.

The fuzzy design in turn can be seen more like an IV approach. Fuzzy RD exploits discontinuities in the probability of treatment conditional on a covariate,  $x_i$ . The discontinuity becomes an instrumental variable for the treatment status.

$$P[S_i = 1 | x_i] = \begin{cases} f_0(x_i) & \text{if } x_i \geq x_0 \\ f_1(x_i) & \text{if } x_i < x_0 \end{cases}$$

Unlike the sharp design the probability of receiving the treatment needs not to change from zero to one at  $x_0$ . Instead, it allows for a smaller jump in the probability of treatment at the threshold. The functions  $f_0(x_i)$  and  $f_1(x_i)$  should differ at  $x_0$ .

The contribution of the present chapter, therefore, is to use a different approach to estimate the causal effect of individual's years of schooling on wages. In order to recover this estimate, we apply a nonparametric bound analysis developed in Manski (1997) and Manski and Pepper (2000) which we describe later.

### 2.3 Partial Identification Bounds: Empirical Framework

In our setting, the realized outcome  $y_j \equiv y_j(s_j)$  is the level of earnings for an individual who receives treatment  $s_j$ , i.e.  $s_j$  is realized years of schooling, both of which are observed. We are interested in learning about the mean treatment response  $E[y(\cdot)]$  and also the average treatment effects  $E[y(s_j)] - E[y(t_j)]$  for  $s_j, t_j \in T, s_j \neq t_j$ , of years of schooling on wages. The selection problem arises as one cannot observe what would have been the counterfactual individual's wage if he or she would have experienced  $t_j$  years of schooling. To simplify notation, the subscript  $j$  will be dropped in what follows.

The identification problem can be shown below:

Decomposing  $E[y(\cdot)]$  by the law of total probability:

$$E[y(t)] = E[y(t)|s=t]P(s=t) + E[y(t)|s \neq t]P(s \neq t) \quad (11)$$

The sampling process identifies  $E[y(t)|s=t]$ ,  $P(s=t)$  and  $P(s \neq t)$ , but it is uninformative about  $E[y(t)|s \neq t]$ . Some assumption have to be imposed in order to get identification. According to Manski (1997), a leading theme in the analysis of treatment response has been to impose strong assumptions in order to identify features of the unknown distribution of the response function or, perhaps, the conditional distributions, which sacrifices credibility in order to achieve strong conclusions. Manski advocates weaker assumptions.

We start with the no-assumption bound, which impose no assumptions at all, and then we move to the introduction of weak but credible assumptions in order to identify regions for the treatment effect.

### 2.3.1 The No-assumption Bounds

According to Manski (1989) it is possible to identify bounds on  $E[y(t)]$  without having to impose any assumptions if the support of the dependent variable is bounded. This is true for our log hourly wage which is bounded within the interval  $[y_{\min}, y_{\max}]$ , where  $y_{\min}$  is the lowest value of observed log wages and  $y_{\max}$  its highest level. Then identification region for the mean treatment effect is the interval equation:

$$E[y(t)|s=t]P(s=t) + y_{\min}P(s \neq t) \leq E[y(t)] \leq E[y(t)|s=t]P(s=t) + y_{\max}P(s \neq t) \quad (12)$$

This bound has width equal to  $(y_{\max} - y_{\min}) P(s \neq t)$ , so the larger the probability that  $z \neq t$ , the larger is the bound interval and the less precise is the information one obtains about the parameter of interest. These bounds can, therefore, be very wide, and in that sense they are not so informative.

### 2.3.2 Identification Assumptions

In order to improve the no-assumptions bounds we follow Manski and Pepper (2000) and impose some assumptions to narrow the width of the intervals of the unknown parameter of interest.

### 2.3.2.1 Monotone Treatment Response (MTR)

Rather than assuming a linear response assumption, a monotone response assumption is assumed, which presumes that our response variable varies monotonically with treatment.

Monotone Treatment Response Assumption: Let  $T$  be an ordered set such as:

$$t_2 \geq t_1 \Rightarrow y(t_2) \geq y(t_1) \quad (13)$$

This assumption asserts that the response varies monotonically with treatment. In other words, increasing years of schooling weakly increases wages.

By combining the MTR assumption with the no-assumptions bounds above, we get MTR bounds:

$$\begin{aligned} E[y | s < t]P(s < t) + E[y | s = t]P(s = t) + y_{\min}P(s > t) \\ \leq E[y(t)] \leq \\ E[y | s > t]P(s > t) + E[y | s = t]P(s = t) + y_{\max}P(s < t) \end{aligned} \quad (14)$$

This weak assumption can narrow the no-assumption bounds, since for the group with  $(s < t)$  under the MTR assumption, their observed mean wage is less than or equal to what their mean wage would have been if they had schooling level  $t$ . So one can use observed mean wage to tighten the lower bound. For the group with  $(s > t)$  the MTR assumption implies that if they would have had schooling level  $t$ , their mean wage would have been lower than or equal to their current mean wage. So the observed mean wage is used to tighten the upper bound.

### 2.3.2.2 Monotone Treatment Selection (MTS)

To tighten the bounds further, additional assumptions can be imposed.

Assuming Monotone Treatment Selection: Let  $T$  be an ordered set.

$$t_2 \geq t_1 \Rightarrow E[y(t) | s = t_2] \geq E[y(t) | s = t_1] \quad (15)$$

The MTS assumption implies that individuals with higher years of schooling have weakly higher mean wage functions than those with lower levels of schooling. In other words, at any education level, more able individuals would be rewarded better than less able individuals. Therefore, instead of assuming exogenous selection into treatment, we assume a

positive selection into it. Through MTS, we incorporate the possibility that years of schooling could be related to individual's ability. Manski and Pepper (2000) showed that combining MTR and MTS assumptions yields a sharp bound on the treatment effect.

By combining the MTR and the MTS assumptions, we get the MTR-MTS bounds:<sup>6</sup>

$$\begin{aligned}
 E[y | s < t]P(s < t) + E[y | s = t]P(s = t) + E[y | s = t]P(z > t) \\
 \leq E[y(t)] \leq \\
 E[y | s > t]P(s > t) + E[y | s = t]P(s = t) + E[y | s = t]P(s < t)
 \end{aligned}
 \tag{16}$$

The validity of the MTS and MTR assumptions could also be questioned, since it considers that the level of schooling determines future earnings and, that individuals with higher ability choose higher levels of schooling and have higher wages. Note, however, that both assumptions consider weak inequalities. Therefore, if the expected future earning is higher for  $t_1$  years of schooling (and if  $t_2 \geq t_1$ ), individuals with higher ability could select  $t_1$  years of schooling which might invalidate the monotonicity assumption. Nevertheless, we can also check its validity through the data.

So under the MTR-MTS assumption, the mean individual's wage should be weakly increasing in the realized years of schooling. That hypothesis must be met in order for the MTR-MTS assumption to be satisfied.

According to Manski and Peper (2000), MTR and MTS assumptions are consistent with human capital theory:

“The MTS assumption is consistent with economic models of schooling choice and wage determinations which predict that persons with higher ability have higher mean wage functions and choose higher level of schooling than do person with lower ability....Human capital theory suggests that, ceteris paribus, the wage that a worker earns weakly increases as a functions of the worker's years of schooling. In this and other settings, MTR assumption has a reasonably firm foundation” (Manski and Pepper, p. 1002, 2000)

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<sup>6</sup> For the full derivation of the bounds, see Manski (1997) and Manski and Pepper (2000).



Chevalier and Lanot (2004) however show that the monotonicity assumptions assumed by Manski are in general not compatible with the decision process assumed by Roy (1951) model. The MTS assumption states that more able individuals who choose higher levels of education would have, on average, higher mean wage functions if they were, otherwise, reassigned to lower education level. The Roy model, on the other hand, does not impose such a requirement on the latent earnings distribution; it only requires that individuals decide based on the highest return.

### 2.3.2.3 Monotone Instrumental Variable (MIV)

Manski and Pepper (2000) propose the use of a monotone instrumental variable (MIV) instead of an IV. Consider the instrumental variable  $z$  which satisfies the mean-independence assumption:

$$E[y(t)|z=u_2] = E[y(t)|z=u_1], \quad u_1 \neq u_2 \quad (17)$$

This assumption asserts that mean response is constant across the population of interest. The MIV assumption, on the other hand, assumes that the mean wage response varies weakly monotonically across specified subpopulations:

$$u_2 \geq u_1 \rightarrow E[y(t)|z=u_2] \geq E[y(t)|z=u_1] \quad (18)$$

Therefore, instead of assuming mean independence, the MIV assumption allows for a weakly monotone relation between the instrumental variable and the mean wage function. Note that the MTS is a special case of MIV when the instrumental variable coincides with the treatment.

### 2.3.2.4 MTR&MTS and MIV

We also combine the MIV assumption with the MTR and MTS assumptions in order to further tighten the bounds on  $E[y(t)]$  and on the average treatment effect  $E[y(t)] - E[y(s)]$ .<sup>7</sup>

Under MTR, MTS, MIV, the bounds on  $E[y(t)]$  are given by:

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<sup>7</sup> For full derivation of these bounds see Manski and Pepper (2000).

$$\begin{aligned}
& \sum_{m \in M} P(z = u) \cdot \left[ \max_{u_1 \leq u} LB_{E[y(t)|z=u_1]} \right] \\
& \leq E[y(t)] \leq \\
& \sum_{m \in M} P(z = u) \cdot \left[ \min_{u_2 \geq u} UB_{E[y(t)|z=u_2]} \right]
\end{aligned} \tag{19}$$

The MTR/MTS/MIV bounds are computed in the following way: the sample is divided into subsamples on the basis of  $z$ , with the MTR/MTS bounds being computed for each subsample. For the subsample in which  $z$  has the value  $u$ , we obtain a lower bound, which is the largest lower bound over all the subsamples where  $z$  is lower than or equal to  $u$ . Similarly, we can obtain an upper bound by taking the smallest upper bound over all subsamples with a value of  $z$  higher than or equal to  $u$ .

To obtain the lower and upper bounds, one can substitute the sample means and empirical probabilities in the equations (4), (10), and (13) and obtain the no-assumptions, MTR&MTS, and MTR&MTS&MIV bounds. Under the assumptions adopted, all bounds are consistent. However, as pointed out by Manski and Pepper (2000), the MIV bounds may have non-negligible finite-sample biases, since such bounds are obtained by taking maxima and minima over a range of nonparametric regression estimates. In order to overcome this issue, Kreider and Pepper (2007) propose a modified MIV estimator that takes into account the finite-sample bias using a nonparametric bootstrap correction. The bias is estimated as:

$$\hat{b} = \left( \frac{1}{k} \sum_{k=1}^K \theta_k \right) - \hat{\theta} \text{ where } \theta_k \text{ is the estimate of the MIV bounds of the } k\text{th bootstrap}$$

replication and  $\hat{\theta}$  is the initial estimate of MIV lower and upper bounds.

The bias-corrected MIV bounds are then obtained as:

$$\hat{\theta}_{bc} = \hat{\theta} - \hat{b} = 2\hat{\theta} - \left( \frac{1}{k} \sum_{k=1}^K \theta_k \right) \text{ where } \hat{\theta}_{bc} \text{ is the estimate bias-corrected MIV bounds.}$$

## 2.4. Review of some Empirical Evidence for the UK

Harmon, Oosterbeek and Walker (2000), reviewed a number of studies which estimate the relationship between education and wages. According to the authors the OLS estimates suggests a return to a year of schooling between 7% and 9% for the UK when a relative

parsimonious specification is used. When increase in school leaving age is used as an instrument for education the estimates suggest a higher return to schooling, which ranges from 11% to 15%.

Walker and Zhu (2001) give a review on a variety of studies on the relationship between education and wages. The vast majority of the estimates for men lie within the 4.1% to 10.8% range. For women the range is from 4.6% to 8.3%. Estimates using IV lies on the 5.5% to 15.2% range for men and are around 9.3% for women, the instruments used were family background and SLA changes. There are still fewer consensuses on the returns to qualification across the studies. Estimates on the return of acquiring a college degree ranges from 26.4% to 71.2%.

Blundell *et al* (2005) employed different parametric and non-parametric methods, in order to recover the effect of education on individual earnings. Using NCDS data - a longitudinal cohort study of all people born in Britain in a given week in March 1958 data - which allows them to control for ability and family background, the authors employed different estimation methods – OLS, IV, control functions methods and matching methods – which rely on different assumptions. The average return to O-level, A-levels and higher education compared with stopping at 16 years of age without qualification was 18%, 24% and 48% respectively.

Harmon and Walker (1995) were the first to use school-leaving age changes to estimate returns to schooling. The authors estimate men's return to schooling for the UK using an IV approach which exploits two changes in the minimum school leaving age (SLA) (the first one increased the SLA from 14 to 15 in 1947 and a further increase in 1973 changes the SLA from 15 to 16). The IV approach yields an estimated return of over 15% while OLS estimate was about 6%. Their study was criticised by Oreopoulos (2006) since they do not adequately control for birth cohort effects. Also, because the later 1973 law change affected a much smaller proportion of the population.

Oreopoulos (2006) using the General Household Survey (GHS) also exploits the first change in the minimum SLA in the UK. The author argued that as almost half of the population of 14 years old were affect by the new minimum age at the time, the estimate of the LATE should be close the average treatment effect. Comparing to LATE estimates from

USA, which also explores changes in minimum SLA, the author found a large gain from compulsory schooling – 10% to 14%.

Focusing on the 1973 SLA in England and Wales and the 1967 SLA in France, Grenet (2009) implements a regression discontinuity design to estimate returns to education. Using the British Labour Force Survey the author estimates a return for men and women of approximately 6-7 per cent and no impact for the French law. According to the author, the difference between the two reforms was that the portion of individuals with no qualifications severely dropped after the introduction of the new SLA in England and Wales, while it kept unchanged in France.

Devereux and Hart (2010) likewise employed a regression discontinuity design allowing comparison of wages for the cohorts born just before and just after the 1947 SLA law change. Using the New Earnings Survey Panel Data-Set (NESPD) they found that the estimates are in fact small and much lower than OLS (around 4 to 7% for men and no evidence of a positive return for women). Grenet (2009) finds somewhat larger estimates since the 1973 SLA change increases the compulsory schooling age from 15 to 16 that also affects the probability of attaining academic credentials.

Bonjour *et al* (2003) use a sample of twins to estimate returns to education. Using a data set for identical female twins they exploit the difference in twins' years of schooling as an instrument for education. The estimates suggest a private return to schooling for women of 7.7 percent. Amin (2011), however, found that these results are driven by one twin pair, which is an outlier in the dataset. If this twin pair is eliminated from the sample the estimated return to education drops to 5.1 percent.

To sum up, it is worth comparing the estimated returns under alternative estimation methods. First, OLS is biased upwards since more able individuals tend to obtain more schooling. IV estimates based on family background variables usually yield high returns to schooling than OLS. These estimates though suffer from bias since background variables is also a proxy for ability and so directly affect wages and schooling. IV estimates based on changes on compulsory schooling laws have usually exceeded OLS estimates since the group of individuals influenced by the law have particularly high returns to education. Those individuals who are induced to stay on at school because of the reform typically have very low levels of schooling. The IV estimator can exceed the convention OLS estimator if the

intervention affects a subgroup with a relatively high marginal return to schooling. The studies reviewed above based on regression discontinuity methods found a much smaller effect for returns to schooling than IV-SLA estimates. These could suggest that the large estimates found using compulsory schooling law changes were based on very high returns to schooling for a number of compliers.

## **2.5. Results**

In this section we estimate rates of return based on qualifications using two different British data sets. We assume a multiple treatment framework distinguishing between discrete values of educational qualifications which are allowed to have different effects on earnings.

We are interested not only on mean wages of a given amount of schooling but also in the difference between mean wages among two subsequent qualifications. Here, the main focus is on the average treatment effect (ATE):  $\Delta(s, t) = E[y(t)] - E[y(s)]$ . To obtain bounds on the ATE, we subtract the lower (upper) bound on  $E[y(s)]$  from the upper (lower) bound on  $E[y(t)]$  to get the upper (lower) bound. As a single rate of return across lifetime does not seem very reasonable, we estimate bounds in different points in time allowing for heterogeneous returns to education over the life cycle.

### **2.5.1 NCDS**

The British NCDS data is a continuing longitudinal survey of all children born in Britain between 3 and 9 of March in 1958. The data contain information on parents' education and social class, mathematics and reading ability at ages 7 and 11, earnings, employment and training since leaving education.

The surveys were undertaken in 1981, 1991, 1999/2000 and 2008/2009 and restricted to full time workers and not self-employed individuals, with the effects being analysed for men and women separately. Estimates were computed only for individuals aged 33 and 42 due the small number of observations for individuals aged 23 and 50 especially in which regards MIV estimation.

The following based measures of education are adopted: no qualifications (or extremely low levels), O-level or vocational equivalent, A-levels or vocational equivalent and some type of higher education qualification (HE).<sup>8</sup>

First, the following analysis compares the results of non-parametric bounds with the results of adopting an ETS assumption. This assumption, yields point identification and assumes that individual's years of schooling are unrelated to unobserved factors affecting individuals' wages (such as ability). A multiple treatment model is used instead of assuming a linear effect of schooling on wages.

Table 2.1 presents the values for  $E(y|s)$  and the number of observations used to estimate the bounds for the NCDS for the sample of men at different ages.<sup>9</sup> The table shows that the observed wages increase with the type of qualification for all ages, in line with the monotonicity hypothesis.<sup>10</sup>

Tables 2.2 and 2.3 show that the data supports the validity of the quintiles of ability in the sense of an MIV. The mean wage function monotonically increases with ability quintiles for all ages and for both math and reading abilities. In order to compute MIV estimates the quintiles are aggregated in two groups: low ability (individuals in the lowest quintiles - 1 to 3) and high ability (individuals in the highest quintiles - 4, 5). Mean (log) wages and the number of observation in each group of ability are also present in tables 2.2 and 2.3.

Figures 2.1 to 2.4 illustrate how the assumptions imposed can narrow the non-parametric bounds. Figure 2.1 shows non-parametric bounds on mean log wages as a function of qualification levels, as well the ETS point estimates for men aged 42.<sup>11</sup> The first panel shows the no-assumption bounds, which are quite wide. In the second panel, the MTR

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<sup>8</sup> O-levels are subject-based qualifications usually taken by 16 years old students in secondary education. A-levels (advanced levels) are academic qualifications taken by students aged 18, completing secondary. A-levels are generally required for higher education entry.

<sup>9</sup> Hourly wages deflated by UK Retail Price Index.

<sup>10</sup>One can informally test the MTR&MTS assumptions checking if the conditional expectation functions  $E(y)$  are weakly increasing in  $t$ . If the joint assumption is rejected, if one is willing to assume that a higher qualification cannot decrease the individual wage (MTR), this implies that the assumption that is failing to hold is the one about selection (MTS).

<sup>11</sup> To allow comparability between years (ages), nominal wages were deflated using the annual Retail Price Index.

assumption is imposed.<sup>12</sup> Despite of reducing the width of the bounds; they are still not very informative. The third panel shows the estimated bounds assuming MTR&MTS. The combined assumptions now strongly reduce the width of the bounds. For the lowest qualification levels (none and O-levels), the ETS point estimates almost coincide with the lower bound, whereas for the highest level (HE) the ETS almost coincides with the upper bound. The last panel adds the MIV assumption. To compute the bounds, we use the quintiles of math ability at age 11 as an MIV.<sup>13</sup> We assume that people with higher quintiles of math ability have weakly higher mean wages functions. Adding this assumption tightens the bounds even further. Comparing MIV bounds with the ETS point estimates, one can note that for most of the qualifications levels the ETS results fall outside the bounds. Thus, ETS underestimates for the lowest qualification levels and overestimates for the highest level.

Figure 2.2 in turn shows bounds on mean log wages for women aged 42. Again, the no-assumptions and MTR bounds are not very informative. On the third panel MTR&MTS assumptions now strongly reduce the width of the bounds. For the lowest qualification levels (None and O-levels), the ETS point estimates coincide with the lower bound, whereas for the HE estimate the ETS coincides with the upper bound. In the fourth panel bounds are estimated using quintiles of math ability at age 11 as an MIV.<sup>14</sup> In the MTR&MTS&MIV bounds the ETS point estimates for None and A-levels coincides with the lower bound while the ETS point estimates for O-levels and HE falls outside the MIV bounds.

So far we have computed bounds on  $E[y(t)]$ , but we are also interested on the average treatment effect:  $\Delta(s, t) = E[y(t)] - E[y(s)]$ . Figure 2.3 and 2.4 shows the lower and upper bounds for the ATE while moving from A-level to HE for men and women aged 42. As before, the no-assumptions bound estimate is quite wide and not very informative. The figure shows how bounds narrow with the inclusion and combination of different assumptions. The MTR assumption reduces the no-assumption lower bound, as it implies that the lower bound cannot be lower than zero. For people with  $t(s > t)$ , the MTR assumption implies that if they would have had a level of schooling  $t$ , their mean wage would have been lower than or equal

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<sup>12</sup>For the no-assumption and MTR bounds we have selected the minimum ( $y_{\min}$ ) and the maximum levels ( $y_{\max}$ ) for the (log) hourly wage in the NCDS data sets. Alternative values do not yield qualitatively different results.

<sup>13</sup> Using reading ability as an MIV yields very similar results.

<sup>14</sup> Using reading ability as an MIV yields very similar results.

to their current mean wage. This mean wage therefore is used to tighten the no-assumptions upper bound. The MTS assumption reduces the upper bound even further. The combination of these two assumptions additionally reduces the bound on ATE. Using the quintiles for math ability as an MIV reduces the ATE even further as in the  $E[y(t)]$  case. One can also note that the bounds for moving from A-level to HE are greater for women, since returns to education for women are on average higher compared to men. Therefore, figures 2.1 to 2.4 clearly show how the assumptions imposed greatly narrow the no-assumption bounds.

Tables 2.4 to 2.5 present bounds for the ATE at different ages assuming MTR&MTS and MTR&MTS&MIV, as well as ETS point estimates.<sup>15</sup> Table 2.4 shows the estimates for men aged 42. The upper bounds on MTR&MTS are in most cases higher than the ETS point estimate. For the results on (O-level, HE) and (None, HE), the ETS point estimate almost coincides with the upper bound on the MTR&MTS. Using math and reading ability as an MIV yield upper bounds that are lower than the MTR&MTS bounds and also lower than the ETS point estimates,

The MTR&MTS&MIV upper bound for moving from no education to O-levels narrows down to 0.16 using quintile of reading ability as an MIV, which is lower than the ETS point estimate of 0.25. The upper bound on return to schooling obtained by moving from O-level to A-level narrows down to approximately 0.10 when using quintiles of ability as an MIV. In the same fashion, the bounds on returns obtained by moving from A-levels to HE narrows down to 0.14, moreover the ETS point estimate fall outside the bias-corrected MIV confidence interval. Using math and reading ability as an MIV narrows down the upper bounds for (None, A-level) to 0.30 and 0.25 respectively, which are below the ETS point estimate of .43. The MTR&MTS&MIV estimates for (O-levels, HE) is point identified since the lower and upper bounds coincide<sup>16</sup> While the ETS point estimate for moving from O-level

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<sup>15</sup> We compute Imbens and Manski (2004) proposed confidence intervals (CI). The CI is computed as:  $CI_{1-\alpha} = (\hat{lb} - c_{IM} \cdot \hat{\sigma}_{lb}, \hat{ub} + c_{IM} \cdot \hat{\sigma}_{ub})$  where  $\hat{lb}$  and  $\hat{ub}$  are the estimated lower and upper bounds and  $\hat{\sigma}$  are the estimated standard errors, obtained using one thousand bootstrap replications. For the MIV case, the  $\hat{lb}$  and  $\hat{ub}$  are replaced by  $\hat{lb}_{bc}$  and  $\hat{ub}_{bc}$  (the bias corrected lower and upper bounds).

<sup>16</sup> These MTR&MTS&MIV lower and upper bounds are computed in a slight different way. Following Blundell *et al* (2007), when the bounds cross, the upper and lower bound are consistent estimates of  $E(y(t))$  under the null that the difference between them is zero. But a more efficient approach is to use a weighted combination of them, that is:  $\hat{E}(y(t)) = \alpha \hat{E}^{LB}[y(t)] + (1 - \alpha) \hat{E}^{UB}[y(t)]$



to HE is 0.47 the MIV upper bound is around 0.25. The effect of increasing one's schooling from no qualification to HE ranges from 0.35 to 0.43, which is well below ETS point estimate.

Table 2.5 shows bounds and ETS point estimates for men aged 33. As discussed above, the MIV bounds are very informative. The upper bound on the returns to education by moving from none to O-levels when MIV is employed almost coincide with ETS point estimates. MTR&MTS&MIV narrows down the estimate for (A-level, HE) to around 0.14, the ETS point estimate also fall outside the bias-corrected MIV confidence interval. The return to education when one moves from O-levels to HE drops down to around 0.22, with an ETS point estimate of 0.38. The upper bound on the return to schooling for individuals moving from no-qualification at all to HE ranges from 0.28 to 0.49, which is well below the ETS point estimates, however its confidence interval is quite wide. The upper bounds for both ages seems quite similar, however the lower bound for the 42 years sample is higher than for 33 years sample, suggesting a higher return to schooling for the former one certainly related to work experience.

In the following analysis, the estimates will focus on the returns for women. It is important to note that women's return to education might suffer from sample selection, since women tend to self-select into labour market.

Harmon, Oosterbeek and Walker (2000) estimates returns to education for women taking into account the sample selection problem using the Family Resource Survey and British Household Panel Survey data. The estimates applying Heckman's sample selection model were almost identical to OLS results for both samples. Median regression analysis (robust to sample bias) results show slightly higher returns to education for women, which could suggest a small effect due to selection in employment. Analyzing data from different European countries the authors showed that countries with the highest rates of female participation have the lowest differences between male and female returns to schooling, while countries with the lowest participation have the largest difference. According to the authors, however, this bias does not appear to be large.

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Where  $\alpha \in [0,1]$  and  $\hat{E}^{LB}[y(t)]$  and  $\hat{E}^{UB}[y(t)]$  are, respectively, the estimates for lower and upper bounds. We report the estimates with  $\alpha = 0.5$ ; alternative values for  $\alpha$  give similar qualitative results.

Vlasblom and Schippers (2004) using the European Labour Force Survey show an increase in female labour market participation between 1992 and 1999 in Europe and in the UK. The estimates also show that participation rates have increased for women both with and without children, and for both low and high-educated women. According to the authors this might be interpreted as a behavioural change between generations reflecting that working wife has become more and more usual in European countries. This could reinforce the fact, suggested by Harmon, Oosterbeek and Walker (2000), that the bias from sample selection in the return to education between men and women in the UK may not be large.

Table 2.6 presents the mean wages by qualification levels, for women aged 42 and 33. The observed wage increases with the type of qualification, which is also in line with our monotonicity assumption. Tables 2.7 and 2.8 also show the validity of using quintiles of math and reading ability as an MIV, with the mean wage function monotonically increasing in ability quintiles for all ages.

Tables 2.9 to 2.10 present the results on bounds as well as the ETS point estimates for the ATE for women aged 42 and 33. In Table 2.9, the MTR&MTS upper bound is generally lower than the ETS point estimates. The bias corrected MIV bounds greatly reduce (increase) the upper (lower) bounds compared to the MTR&MTS. The MIV upper bound for (O-levels, A-levels) sharply drops to 0.08, well below the ETS point estimate of 0.40. The MIV upper bound for (O-levels, HE) narrows down to 0.32 while the ETS point estimate is 0.69. Using quintile of ability as an MIV reduces the upper bound for (None, HE) further to 0.58, the ETS point estimate also falls outside the bias-corrected MIV confidence interval.

In Table 2.10 the MIV upper bound estimates for (O-levels, A-levels) are around 0.12 while the ETS point estimate is 0.21. The MIV returns to education from moving from no-qualifications to A-levels ranges from 0.24 to 0.37, the ETS point estimate of 0.45 is then outside this range. The bounds for quintile of ability as an MIV for moving from no-qualifications to HE is also informative with the upper bound dropping to 0.53 for reading ability.

The estimates also show that the MIV upper bounds are higher for women than for men, especially for (O-level, HE) and (None, HE), which is in line with the literature on returns to education. One should also note that bounds on MIV reading ability are more informative for women's estimates.

### 2.5.2 General Household Survey (GHS)

Bounds on return to education are also computed using the General Household Survey (GHS) from 1979 to 2006. GHS has the advantage to allow us to use the change in the minimum school leaving age as an MIV, an instrument often employed in the literature (see Harmon and Walker (1995) for example). GHS is a continuous survey, which collects a range of information on households in Great Britain. The survey has been carried out continuously since 1971 except for breaks in 1997/98 and 1999/2000. The first increase in the minimum SLA, from 14 to 15, was in 1947. A subsequent increase in the SLA occurred in 1973, which increased the minimum age from 15 to 16. So the exogenous change in the minimum SLA is used as an MIV. We assume that people affected by the changes in SLA have weakly higher mean wages functions since individuals exposed to these changes might have acquired more years of schooling.

Individuals who entered their 14<sup>th</sup> year between 1947 and 1971 and thereby faced a minimum SLA of 15 and those who entered their 15<sup>th</sup> year after 1972 and faced a minimum SLA of 16, were all affected by the changes in law.

The same education based measures as in NCDS were adopted: no qualifications (or extremely low levels), O-level or vocational equivalent, A-levels or vocational equivalent, and those with some sort of higher education qualification (HE). The sample was restricted to British-born adults aged between 30 and 65, full time workers and not self-employed. As we focus only on the second SLA change (SLA 16) we drop from the sample individuals who faced the minimum school leaving age of 14.

Tables 2.11 presents the mean wages by qualification levels for men and women respectively.<sup>17</sup> The observed mean wages increase with qualification levels for both genders. This is in accordance with the adopted MTR&MTS assumptions.

Table 2.12 shows the mean wages according to the SLA-MIV variable. The latter is defined as a binary variable that equals one if the SLA is 16 and zero otherwise. The results show evidence supporting the validity of the SLA variable as an MIV, since the mean wage function monotonically increases.

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<sup>17</sup>Annual wages deflated by UK Retail Price Index.

Table 2.13 presents bounds and ETS point estimates on ATE for men using GHS data. The upper bounds on MTR&MTS are not very informative since they are higher than the ETS point estimates. Adding the change in SLA as an MIV though reduces the width of the bounds. The ETS point estimate almost coincide with the SLA-MIV upper bound for (None, O-levels). Using SLA as an MIV reduces the bounds on (O-levels, A-levels) and (A-levels, HE) further to 0.12 and 0.15, lower than ETS point estimates. The resulting upper bound on the return to schooling obtained by moving from no qualifications to A-levels narrows down to 0.39. In the same fashion, the effect of increasing one's schooling from O-levels to HE narrows down to 0.26, which is well below the ETS point estimates of 0.48. Finally the SLA-MIV reduces the upper bound for (None, HE) further to 0.53, the ETS point estimate also falls outside the bias-corrected MIV confidence interval.

Table 2.14 presents the results for women. Again, MTR&MTS bounds are not very informative. The SLA-MIV upper bound obtained by moving from no-qualifications to O-levels shrinks to almost 0.17. Additionally, the upper bound when one goes from O-levels to A-levels also reduces to 0.26, below the ETS point estimate of 0.34. The SLA-MIV upper bounds on returns to education for (None, A-levels) and (O-levels, HE) shrink to 0.47 and 0.45, well below the ETS point estimate of 0.663 and 0.62 respectively. Finally the MIV upper bounds for moving one's education from no qualifications to HE is also with the upper bound dropping to 0.59, the ETS point estimate also falls outside the bias-corrected MIV confidence interval.

## 2.6. Comparing Partial Identification Bounds to Others Identification Approaches

Manski and Pepper (2000), Gonzalez (2005) and De Haan (2011), compare their non-parametric bounds on ATE with some parametric (IV and OLS) estimates found in the literature.<sup>18</sup> Such a comparison is possible since the joint MTR&MTS assumption on Manski and Pepper (2000) and the MTR&MTS&MIV assumption employed in Gonzalez (2005) and De Haan (2011) have enough identification power. Moreover, following Gonzalez (2005), De Haan (2011), and Giustinelli (2011) we compare non-parametric bounds on ATEs under

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<sup>18</sup> Manski and Pepper (2000) compute bounds on returns to schooling, Gonzalez (2005) bounds on returns to language skills while De Haan (2011) compute bounds on the effects of parents' schooling on child's schooling.

MTR&MTS and MTR&MTS&MIV with parametric OLS and IV estimates performed on the same sample.<sup>19</sup>

Non-parametric bounds are then compared with estimates that employed different identification approaches. First, bounds are compared with the estimates computed by a linear OLS (ETS) and IV regression model (using change in SLA as an IV), performed on the same sample. According to Giustinelli (2011), any point-estimate obtained under stronger assumptions should lie within the non-parametric bounds if the econometric model is correctly specified.

Table 2.15 shows the results in which the change in SLA is used as an instrument in a 2SLS regression. As results so far have basically focused on ATE, a 2SLS regression model is estimated for (None, O-levels) and (O-levels, A-levels). We focus only on lower qualifications because as pointed out by Chevalier et al (2004) individuals at the low end of the qualification distribution were the most affected by this instrument.

Table 2.15 panel A shows that although the ETS point estimate almost coincide with the SLA-IV upper bounds on (None, O-levels), the latter is lower than the linear IV point estimate of 0.34. For women though, the MIV upper bound is well below both the ETS and IV point estimates. Panel B shows estimates for (O-levels, A-levels). Using SLA as an MIV yields bounds that are also lower than the linear OLS and IV point estimates for both men and women.

Non-parametric bound estimates are now compared with some point estimates reported in the empirical literature. Blundell et al. (2005) employing parametric techniques and using the NCDS data, computed returns to qualifications for men aged 33. Using several OLS and matching models, they found estimates for moving from no-qualification to HE that ranges from 44% to 59%. The lower bound of their point estimates coincides with our previous result for the Math\_MIV upper bound, as shown in Table 2.5.

When moving from O-levels to HE, MTR&MTS&MIV yields an estimate of around 0.22. Blundell's (2005) estimates fall outside these bounds, as they lie in the 0.30 to 0.38 interval. By comparing the results obtained for moving from no-qualifications to A-levels, Math\_MIV estimates a rate of return between (0.16, 0.30). All the point estimates found by

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<sup>19</sup> Giustinelli (2011) develops non-parametric bounds on quantiles and compute bounds on returns to schooling using an Italian data set.

Blundell (2005) lie exactly within this interval. The MIV bounds on  $\Delta(2,3)$  are well below the point estimates using other identification approaches which ranges from 0.24 to 0.29. The point estimates reported for  $\Delta(1,2)$  lie in the bias-corrected MIV confidence interval. This is also true for the  $\Delta(0,1)$  estimates.

Dearden (1998) used NCDS data to compute the returns to qualifications for men and women. The author used an OLS approach and found a 50% return to a degree for males and 64% for females. These point estimates though are higher than the upper bound for MIV estimates reported in tables 2.5 and 2.10.

Walker and Zhu (2001), using LFS data from 1993-2000, found a yearly return to schooling to bachelor degree for men ranging from 0.46 to 0.51 and to a master's degree from 0.50 to 0.58. Although the HE measure used in this chapter indistinctively encompasses both qualifications, their point estimates almost coincide with the upper bounds of SLA-MIV estimates.

## **2.7 Summary and Conclusions**

This chapter aimed at identifying regions for the returns to schooling in the UK. In order to do so, Manski (1997) and Manski and Pepper (2000) non-parametric bounds were applied. The nonparametric bounds analysis gives bounds on returns to education by relying on a set of weak and, in part, testable assumptions. A comparison with the results using other identification approaches shows that non-parametric bounds give informative estimates on the returns to education. The estimates show some evidence that the returns to education - computed through weaker assumptions - are smaller than some of the point estimates reported in the literature. This is especially true for higher qualifications.

Specifically the method does not assume linearity of the response function nor exogenous selection into treatment. Moreover, instead of using the traditional IV approach to tackle the selection problem, which is usually prone to criticisms, a MIV was assumed, which is a weaker and often more credible assumption.

Okumura and Isui (2010), which also found smaller estimates for the return to schooling in the US, argued that the higher returns to schooling computed in previous studies could be due to the linear response assumption. The results found in Belzil and Hansen (2002)

cast doubts on the validity of very high returns reported in the empirical literature.<sup>20</sup> The OLS estimates, which rely on the hypothesis that the endogenous schooling variable is orthogonal to unobserved determinants of wages, can critically biased upward the average return to education. The IV estimator is usually applied in a linear wage function, which leads to a bias in the estimates. Moreover, the IV approach might overestimate the returns to education if the instruments are invalid.<sup>21</sup>

This work has also focused on the estimation of local (marginal) returns to schooling instead of the average returns. As pointed out by Belzil and Hansen (2002), estimates which impose equality between local and average returns to schooling will be affected by the relative frequency of individuals with high and low taste for schooling. The average effect will be biased towards the local returns, which is most recurrent in sample data. In such a case, local returns could lead to more reliable estimates of the true return.

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<sup>20</sup> The authors estimate a structural dynamic programming model of schooling decisions with unobserved heterogeneity in school ability and market ability.

<sup>21</sup> Carneiro and Heckman (2002) criticize the valid of some of the instruments usually employed in the literature, showing that they are either correlated with ability proxies or uncorrelated with realized years of schooling.

Table 2.1: Mean (log) wages by qualification levels - NCDS by ages - Men

| S       | Mean (log) wages<br>(42 years) | N     | Mean (log) wages<br>(33 years) | N     |
|---------|--------------------------------|-------|--------------------------------|-------|
| None    | 2.16                           | 234   | 2.03                           | 225   |
| O-level | 2.41                           | 1,186 | 2.29                           | 1,200 |
| A-level | 2.58                           | 710   | 2.39                           | 712   |
| HE      | 2.86                           | 1,293 | 2.66                           | 1,065 |
|         |                                | 3,423 |                                | 3,202 |

Note: None: no or low qualifications; O-level: O-levels or vocational equivalent; A-levels: A-levels or vocational equivalent; HE: some type of higher education qualification. Real (log) hourly wages. N=number of observations.

Table 2.2: Mean (log) wages by Math Ability at 11 - NCDS - Men

| Quintiles of Math<br>Ability | Mean (log) wage<br>(42 years) | Mean (log) wage<br>(33 years) |
|------------------------------|-------------------------------|-------------------------------|
| 1                            | 2.243                         | 2.147                         |
| 2                            | 2.449                         | 2.279                         |
| 3                            | 2.539                         | 2.378                         |
| 4                            | 2.689                         | 2.484                         |
| 5                            | 2.886                         | 2.644                         |
| Low ability                  | 2.424                         | 2.281                         |
|                              | N=1,838                       | N=1,697                       |
| High ability                 | 2.795                         | 2.569                         |
|                              | N=1,585                       | N=1,505                       |

Note: Individuals in the lowest three quintiles were classified as “lower ability” and the remainder were classified as “higher ability”. Real (log) hourly wages.



Table 2.3: Mean (log) wages by Reading Ability at 11 - NCDS – Men

| Quintiles of Math Ability | Mean (log) wage (42 years) | Mean (log) wage (33 years) |
|---------------------------|----------------------------|----------------------------|
| 1                         | 2.278                      | 2.172                      |
| 2                         | 2.449                      | 2.295                      |
| 3                         | 2.550                      | 2.380                      |
| 4                         | 2.676                      | 2.471                      |
| 5                         | 2.884                      | 2.641                      |
| Low ability               | 2.433<br>N=1840            | 2.289<br>N=1,699           |
| High ability              | 2.785<br>N=1583            | 2.561<br>N=1,503           |

Note: Individuals in the lowest three quintiles were classified as “lower ability” and the remainder were classified as “higher ability”. Real (log) hourly wages.

Table 2.4: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications - NCDS 42 years – Men

|               | ETS<br>$\beta$        | MTR&MTS       |       | MTR & MTS & MIV<br>(IV=Math Score) |       | MTR & MTS & MIV<br>(IV=Reading Score) |       |
|---------------|-----------------------|---------------|-------|------------------------------------|-------|---------------------------------------|-------|
|               |                       |               |       | Bias Corrected                     |       | Bias Corrected                        |       |
|               |                       | LB            | UB    | LB                                 | UB    | LB                                    | UB    |
| $\Delta(0,1)$ | 0.246<br>(0.18; 0.31) | 0<br>(0;0.52) | 0.452 | 0.113<br>[0.05; 0.42]              | 0.217 | 0.095<br>[0.05; 0.34]                 | 0.160 |
| $\Delta(1,2)$ | 0.185<br>(0.14; 0.23) | 0<br>(0;0.34) | 0.307 | 0.095<br>[0.06; 0.13]              | 0.095 | 0.102<br>[0.7; 0.14]                  | 0.102 |
| $\Delta(2,3)$ | 0.28<br>(0.23; 0.32)  | 0<br>(0;0.41) | 0.375 | 0.140<br>[0.11; 0.17]              | 0.140 | 0.143<br>[0.11; 0.18]                 | 0.143 |
| $\Delta(0,2)$ | 0.432<br>(0.36; 0.50) | 0<br>(0;0.59) | 0.536 | 0.230<br>[0.17; 0.50]              | 0.301 | 0.224<br>[0.17; 0.43]                 | 0.247 |
| $\Delta(1,3)$ | 0.465<br>(0.43; 0.50) | 0<br>(0;0.52) | 0.482 | 0.237<br>[0.20; 0.27]              | 0.237 | 0.246<br>[0.21; 0.28]                 | 0.246 |
| $\Delta(0,3)$ | 0.711<br>(0.64; 0.78) | 0<br>(0;0.77) | 0.712 | 0.371<br>[0.34; 0.63]              | 0.427 | 0.352<br>[0.32; 0.58]                 | 0.400 |

Note: Dependent variable is individuals' real (log) hourly wages. Numbers between parentheses are Imbens-Manski 95% confidence intervals. Numbers between brackets are Imbens-Manski 95% confidence intervals using bias-corrected MIV bounds. Levels of qualifications are (0) none, (1) O-level or equivalent, (2) A-level or equivalent, and (3) HE.

Table 2.5: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications - NCDS 33 years – Men

|               | ETS                    | MTR&MTS       |       | MTR & MTS & MIV<br>(IV=Math Score) |       | MTR & MTS & MIV<br>(IV=Reading Score) |       |
|---------------|------------------------|---------------|-------|------------------------------------|-------|---------------------------------------|-------|
|               |                        |               |       | Bias Corrected                     |       | Bias Corrected                        |       |
|               |                        |               |       | LB                                 | UB    | LB                                    | UB    |
| $\Delta(0,1)$ | 0.265<br>(0.21;0.32)   | 0<br>(0;0.45) | 0.410 | .074<br>[0.03; 0.42]               | .251  | 0.073<br>[0.03; 0.45]                 | 0.283 |
| $\Delta(1,2)$ | 0.106<br>(0.07; 0.14)  | 0<br>(0;0.24) | 0.212 | 0.065<br>[0.04; 0.09]              | 0.065 | 0.062<br>[0.04; 0.09]                 | 0.062 |
| $\Delta(2,3)$ | 0.260<br>(0.23; 0.30)  | 0<br>(0;0.36) | 0.328 | 0.138<br>[0.11; 0.17]              | 0.138 | 0.149<br>[0.12; 0.18]                 | 0.149 |
| $\Delta(0,2)$ | 0.371<br>(0.32 ; 0.43) | 0<br>(0;0.50) | 0.458 | 0.160<br>[0.11; 0.46]              | 0.295 | 0.153<br>[0.11; 0.50]                 | 0.328 |
| $\Delta(1,3)$ | 0.367<br>(0.34 ; 0.40) | 0<br>(0;0.42) | 0.386 | 0.213<br>[0.18; 0.23]              | 0.213 | 0.221<br>[0.19; 0.25]                 | 0.221 |
| $\Delta(0,3)$ | 0.632<br>(0.58; 0.68)  | 0<br>(0;0.68) | 0.633 | 0.295<br>[0.26; 0.62]              | 0.445 | 0.281<br>[0.25; 0.69]                 | 0.490 |

Note: Dependent variable is individuals' real (log) hourly wages. Numbers between parentheses are Imbens-Manski 95% confidence intervals. Numbers between brackets are Imbens-Manski 95% confidence intervals using bias-corrected MIV bounds. Levels of qualifications are (0) none, (1) O-level or equivalent, (2) A-level or equivalent, and (3) HE.

Table 2.6: Mean (log) wages by qualification levels - NCDS by ages – Women

| S       | Mean (log) wages |       | N    | Mean (log) wages |  | N |
|---------|------------------|-------|------|------------------|--|---|
|         | 42 years         |       |      | 33 years         |  |   |
| None    | 1.83             | 261   | 1.66 | 216              |  |   |
| O-level | 1.98             | 1,592 | 1.89 | 1,288            |  |   |
| A-level | 2.12             | 506   | 2.10 | 377              |  |   |
| HE      | 2.52             | 1,118 | 2.44 | 780              |  |   |
|         |                  | 3,447 |      | 2,661            |  |   |

Notes: None: no or low qualifications; O-level: O-levels or vocational equivalent; A-levels: A-levels or vocational equivalent; HE: some type of higher education qualification. Real (log) hourly wages. N=number of observations.

Table 2.7: Mean (log) wages by Math Ability at 11 - NCDS - Women

| Quintiles of Math Ability | Mean (log) wage (42 years) | Mean (log) wage (33 years) |
|---------------------------|----------------------------|----------------------------|
| 1                         | 1.910                      | 1.758                      |
| 2                         | 2.026                      | 1.921                      |
| 3                         | 2.124                      | 2.030                      |
| 4                         | 2.272                      | 2.159                      |
| 5                         | 2.441                      | 2.325                      |
| Low ability               | 2.033<br>N=2,014           | 1.923<br>N=1,502           |
| High ability              | 2.350<br>N=1,433           | 2.238<br>N=1,159           |

Notes: Individuals in the lowest three quintiles were classified as “lower ability” and the remainder were classified as “higher ability”. Real (log) hourly wages.

Table 2.8: Mean (log) wages by Reading Ability at 11 - NCDS – Women

| Quintiles of Math Ability | Mean (log) wage (42 years) | Mean (log) wage (33 years) |
|---------------------------|----------------------------|----------------------------|
| 1                         | 1.918                      | 1.802                      |
| 2                         | 2.012                      | 1.883                      |
| 3                         | 2.117                      | 2.019                      |
| 4                         | 2.259                      | 2.177                      |
| 5                         | 2.451                      | 2.305                      |
| Low ability               | 2.026<br>N=1,967           | 1.912<br>N=1,445           |
| High ability              | 2.346<br>N=1,490           | 2.236<br>N=1,216           |

Notes: Individuals in the lowest three quintiles were classified as “lower ability” and the remainder were classified as “higher ability”. Real (log) hourly wages.

Table 2.9: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications – NCDS 42 years – Women

|               | ETS<br>$\beta$        | MTR&MTS        |                    | MTR & MTS & MIV<br>(IV=Math Score) |                       | MTR & MTS & MIV<br>(IV=Reading Score) |                      |
|---------------|-----------------------|----------------|--------------------|------------------------------------|-----------------------|---------------------------------------|----------------------|
|               |                       |                |                    | Bias Corrected                     |                       | Bias Corrected                        |                      |
|               |                       | LB             | UB                 | LB                                 | UB                    | LB                                    | UB                   |
| $\Delta(0,1)$ | 0.221<br>(0.18; 0.26) | 0<br>(0; 0.42) | 0.360<br>(0; 0.42) | 0.04<br>[0.0; 0.47]                | 0.234<br>[0.0; 0.47]  | 0.026<br>[0.0;0.25]                   | 0.073<br>[0.0;0.25]  |
| $\Delta(1,2)$ | 0.401<br>(0.38; 0.46) | 0<br>(0; 0.33) | 0.297<br>(0; 0.33) | 0.076<br>[0.04; 0.11]              | 0.076<br>[0.04; 0.11] | 0.081<br>[0.05;0.11]                  | 0.081<br>[0.05;0.11] |
| $\Delta(2,3)$ | 0.262<br>(0.19; 0.34) | 0<br>(0; 0.53) | 0.488<br>(0; 0.53) | 0.231<br>[0.18; 0.31]              | 0.248<br>[0.18; 0.31] | 0.232<br>[0.20;0.27]                  | 0.235<br>[0.20;0.27] |
| $\Delta(0,2)$ | 0.651<br>(0.61; 0.69) | 0<br>(0; 0.50) | 0.442<br>(0; 0.50) | 0.127<br>[0.10; 0.50]              | 0.305<br>[0.10; 0.50] | 0.117<br>[0.08;0.32]                  | 0.165<br>[0.08;0.32] |
| $\Delta(1,3)$ | 0.692<br>(0.62; 0.77) | 0<br>(0; 0.60) | 0.562<br>(0; 0.60) | 0.301<br>[0.27; 0.39]              | 0.322<br>[0.27; 0.39] | 0.304<br>[0.27;0.38]                  | 0.321<br>[0.27;0.38] |
| $\Delta(0,3)$ | 0.913<br>(0.83; 0.99) | 0<br>(0; 0.77) | 0.707<br>(0; 0.77) | 0.316<br>[0.28; 0.82]              | 0.581<br>[0.28; 0.82] | 0.321<br>[0.29;0.59]                  | 0.405<br>[0.29;0.59] |

Note: Dependent variable is individuals' real (log) hourly wages. Numbers between parentheses are Imbens-Manski 95% confidence intervals. Numbers between brackets are Imbens-Manski 95% confidence intervals using bias-corrected MIV bounds. Levels of qualifications are (0) none, (1) O-level or equivalent, (2) A-level or equivalent, and (3) HE.

Table 2.10: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications – NCDS 33 years – Women

|               | ETS<br>$\beta$        | MTR&MTS       |       | MTR & MTS & MIV<br>(IV=Math Score) |       | MTR & MTS & MIV<br>(IV=Reading Score) |       |
|---------------|-----------------------|---------------|-------|------------------------------------|-------|---------------------------------------|-------|
|               |                       |               |       | Bias Corrected                     |       | Bias Corrected                        |       |
|               |                       | LB            | UB    | LB                                 | UB    | LB                                    | UB    |
| $\Delta(0,1)$ | 0.237<br>(0.18; 0.29) | 0<br>(0;0.48) | 0.433 | 0.069<br>[0.02; 0.43]              | 0.206 | 0.076<br>[0.03; 0.29]                 | 0.107 |
| $\Delta(1,2)$ | 0.214<br>(0.17; 0.26) | 0<br>(0;0.38) | 0.336 | 0.12<br>[0.09; 0.15]               | 0.12  | 0.117<br>[0.8; 0.15]                  | 0.117 |
| $\Delta(2,3)$ | 0.343<br>(0.30; 0.39) | 0<br>(0;0.52) | 0.484 | 0.130<br>[0.08; 0.33]              | 0.269 | 0.163<br>[0.10; 0.34]                 | 0.269 |
| $\Delta(0,2)$ | 0.451<br>(0.39; 0.52) | 0<br>(0;0.60) | 0.554 | 0.149<br>[0.11; 0.59]              | 0.367 | 0.175<br>[0.13; 0.43]                 | 0.241 |
| $\Delta(1,3)$ | 0.557<br>(0.52; 0.59) | 0<br>(0;0.61) | 0.578 | 0.290<br>[0.26; 0.41]              | 0.349 | 0.298<br>[0.26; 0.43]                 | 0.368 |
| $\Delta(0,3)$ | 0.795<br>(0.74; 0.85) | 0<br>(0;0.84) | 0.795 | 0.315<br>[0.28; 0.84]              | 0.60  | 0.324<br>[0.29; 0.71]                 | 0.525 |

Note: Dependent variable is individuals' real (log) hourly wages. Numbers between parentheses are Imbens-Manski 95% confidence intervals. Numbers between brackets are Imbens-Manski 95% confidence intervals using bias-corrected MIV bounds. Levels of qualifications are (0) none, (1) O-level or equivalent, (2) A-level or equivalent, and (3) HE.

Table 2.11: Mean (log) wages by schooling levels by gender – GHS

| Z       | Mean (log) wages<br>Men | N      | Mean (log) wages<br>Woman | N      |
|---------|-------------------------|--------|---------------------------|--------|
| None    | 9.64                    | 7,237  | 8.70                      | 6,895  |
| O-level | 9.87                    | 8,939  | 9.08                      | 10,332 |
| A-level | 10.07                   | 4,081  | 9.36                      | 3,001  |
| HE      | 10.35                   | 7,655  | 9.70                      | 6,930  |
|         |                         | 27,912 |                           | 27,158 |

Real (log) annual wages. N=number of observations.

Table 2.12: Mean (log) wages by SLA-MIV variable - GHS

| SLA-MIV | Mean (log) wage<br>(Men) | Mean (log) wage<br>(Woman) |
|---------|--------------------------|----------------------------|
| SLA16=0 | 9.78<br>N=10,320         | 8.74<br>N=7,293            |
| SLA16=1 | 10.09<br>N= 17,592       | 9.34<br>N= 19,865          |

Real (log) annual wages.

Table 2.13: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications - GHS – Men

|               | ETS                    | MTR&MTS        |       | MTR & MTS & MIV        |       |
|---------------|------------------------|----------------|-------|------------------------|-------|
|               | $\beta$                | Bias Corrected |       |                        |       |
|               |                        | LB             | UB    | LB                     | UB    |
| $\Delta(0,1)$ | 0.234<br>(0.20; 0.25)  | 0<br>(0; 40)   | 0.362 | 0.106<br>[0.08; 0.296] | 0.242 |
| $\Delta(1,2)$ | 0.205<br>(0.17 ; 0.24) | 0<br>(0; 0.36) | 0.339 | 0.122<br>[0.09; 0.15]  | 0.122 |
| $\Delta(2,3)$ | 0.272<br>(0.24; 0.31)  | 0<br>(0; 0.48) | 0.451 | 0.101<br>[0.06; 0.19]  | 0.147 |
| $\Delta(0,2)$ | 0.436<br>(0.40; 0.47)  | 0<br>(0; 0.54) | 0.511 | 0.202<br>[0.17; 0.45]  | 0.394 |
| $\Delta(1,3)$ | 0.477<br>(0.45; 0.50)  | 0<br>(0; 0.56) | 0.537 | 0.256<br>[0.22; 0.28]  | 0.256 |
| $\Delta(0,3)$ | 0.708<br>(0.68; 0.73)  | 0<br>(0; 0.73) | 0.704 | 0.31<br>[0.29; 0.59]   | 0.534 |

Note: Dependent variable is individuals' real (log) annual wages. Numbers between parentheses are Imbens-Manski 95% confidence intervals. Numbers between brackets are Imbens-Manski 95% confidence intervals using bias-corrected MIV bounds. Levels of qualifications are (0) none, (1) O-level or equivalent, (2) A-level or equivalent, and (3) HE.

Table 2.14: ETS Point Estimates and Nonparametric Bounds on Returns to Qualifications - GHS –Women

|               | ETS                   | MTR&MTS        |       | MTR & MTS & MIV       |       |
|---------------|-----------------------|----------------|-------|-----------------------|-------|
|               | $\beta$               | Bias Corrected |       |                       |       |
|               |                       | LB             | UB    | LB                    | UB    |
| $\Delta(0,1)$ | 0.383<br>(0.36; 0.41) | 0<br>(0; 0.61) | 0.562 | 0.167<br>[0.14; 0.19] | 0.167 |
| $\Delta(1,2)$ | 0.280<br>(0.24; 0.32) | 0<br>(0; 0.50) | 0.463 | 0.156<br>[0.06; 0.24] | 0.156 |
| $\Delta(2,3)$ | 0.340<br>(0.39; 0.38) | 0<br>(0; 0.64) | 0.590 | 0.134<br>[0.05; 0.43] | 0.263 |
| $\Delta(0,2)$ | 0.663<br>(0.62; 0.71) | 0<br>(0; 0.78) | 0.749 | 0.158<br>[0.05; 0.50] | 0.466 |
| $\Delta(1,3)$ | 0.618<br>(0.59; 0.65) | 0<br>(0; 0.74) | 0.714 | 0.246<br>[0.16; 0.50] | 0.451 |
| $\Delta(0,3)$ | 1.01<br>(0.96; 1.03)  | 0<br>(0; 1.05) | 1.02  | 0.434<br>[0.35; 0.62] | 0.594 |

Note: Dependent variable is individuals' real (log) annual wages. Numbers between parentheses are Imbens-Manski 95% confidence intervals. Numbers between brackets are Imbens-Manski 95% confidence intervals using bias-corrected MIV bounds. Levels of qualifications are (0) none, (1) O-level or equivalent, (2) A-level or equivalent, and (3) HE.

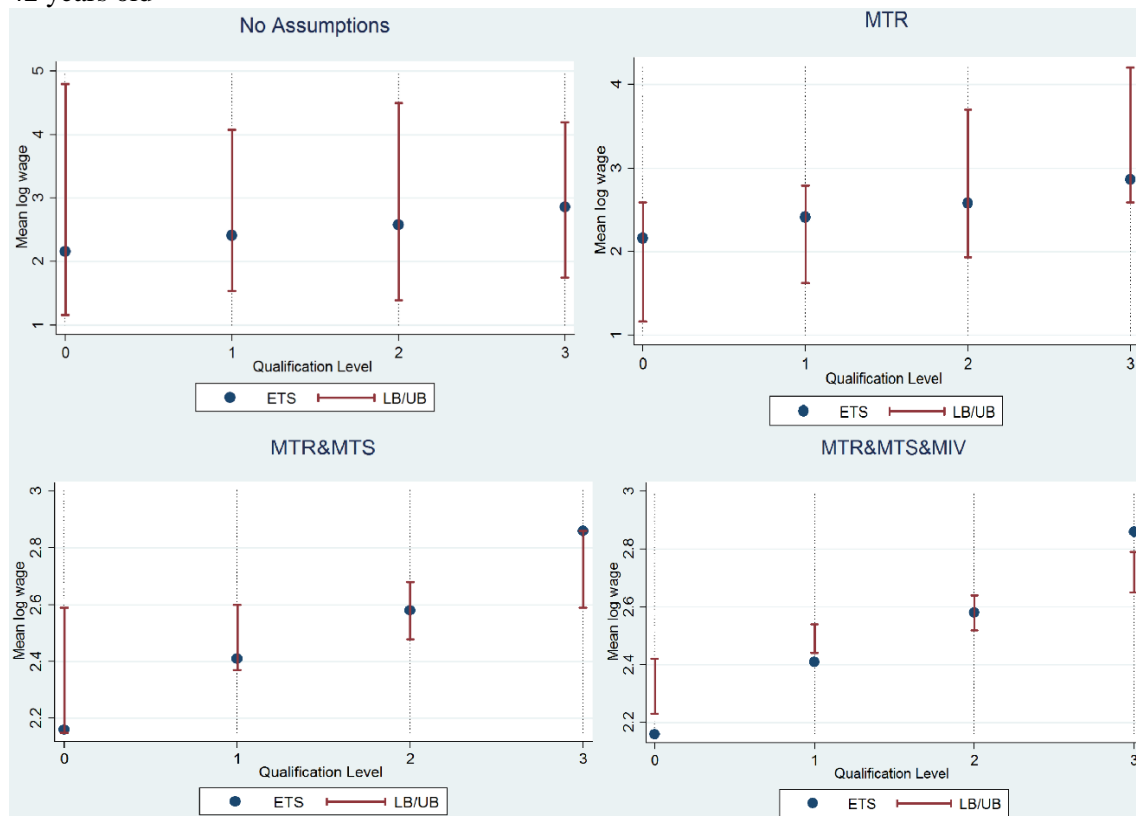


Table 2.15: Returns to Schooling Using Change in SLA an (M)IV

|                | OLS<br>(ETS)           | IV<br>Change in SLA   | MTR & MTS & MIV        |       |
|----------------|------------------------|-----------------------|------------------------|-------|
|                |                        |                       | Bias Corrected<br>LB   | UB    |
| <i>Panel A</i> |                        |                       |                        |       |
|                |                        |                       | Men                    |       |
| $\Delta(0,1)$  | 0.234<br>(0.20; 0.25)  | 0.339<br>(0.29; 0.39) | 0.106<br>[0.08; 0.296] | 0.242 |
|                |                        |                       | Women                  |       |
| $\Delta(0,1)$  | 0.383<br>(0.36; 0.41)  | 0.654<br>(0.61; 0.69) | 0.167<br>[0.14; 0.19]  | 0.167 |
| <i>Panel B</i> |                        |                       |                        |       |
|                |                        |                       | Men                    |       |
| $\Delta(1,2)$  | 0.205<br>(0.17 ; 0.24) | 0.55<br>(0.49; 0.60)  | 0.122<br>[0.09; 0.15]  | 0.122 |
|                |                        |                       | Women                  |       |
| $\Delta(1,2)$  | 0.280<br>(0.24; 0.32)  | 1.516<br>(1.46; 1.70) | 0.156<br>[0.06; 0.24]  | 0.156 |

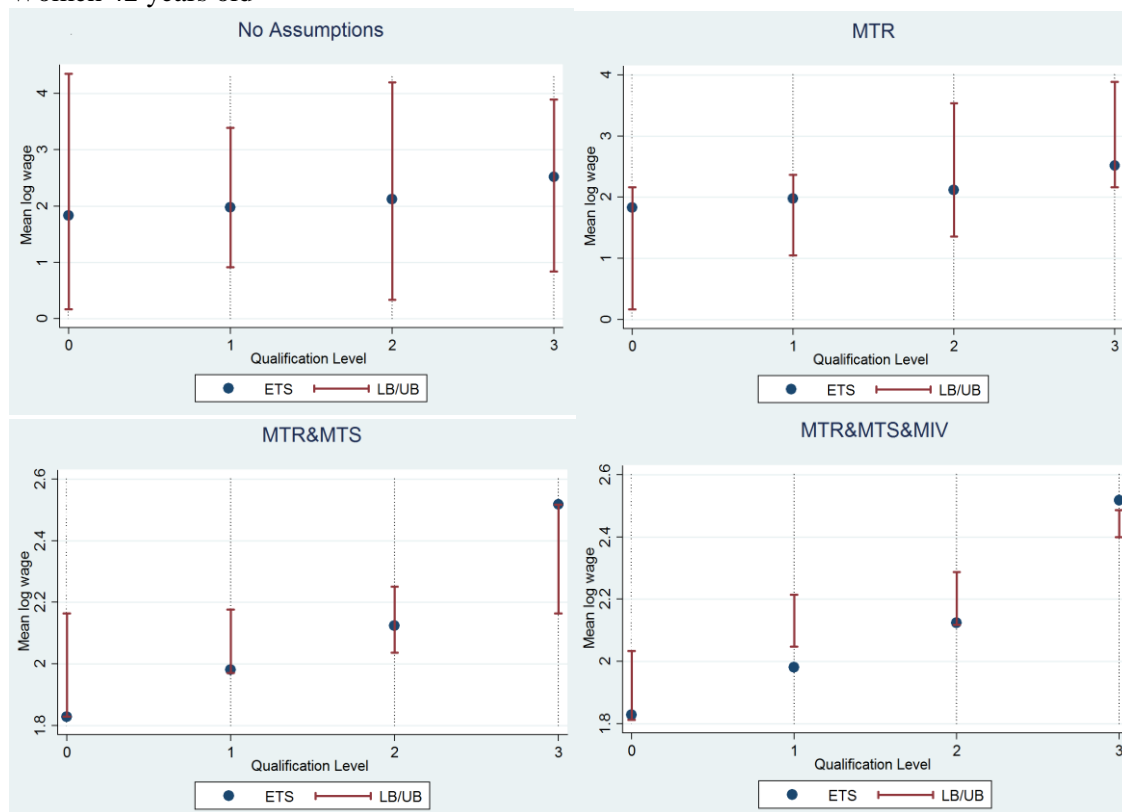
Note: Dependent variable is individuals' real (log) annual wages. Numbers between parentheses are Imbens-Manski 95% confidence intervals. Numbers between brackets are Imbens-Manski 95% confidence intervals using bias-corrected MIV bounds. Levels of qualifications are (0) none, (1) O-level or equivalent and (2) A-level or equivalent.

Figure 2.1: Wages as a function of Qualifications levels: bounds and ETS point estimates – NCDS Men 42 years old



Notes: Qualifications levels are: (0) none, (1) O-levels, (2) A-levels, and (3) HE. MIV bias corrected bounds.

Figure 2.2: Wages as a function of Qualifications levels: bounds and ETS point estimates – NCDS Women 42 years old



Notes: Qualifications levels are: (0) none, (1) O-levels, (2) A-levels, and (3) HE. MIV bias corrected bounds.

Figure 2.3: Wages as a function of Qualifications levels: bounds for (A-level, HE) – NCDS Men 42 years old

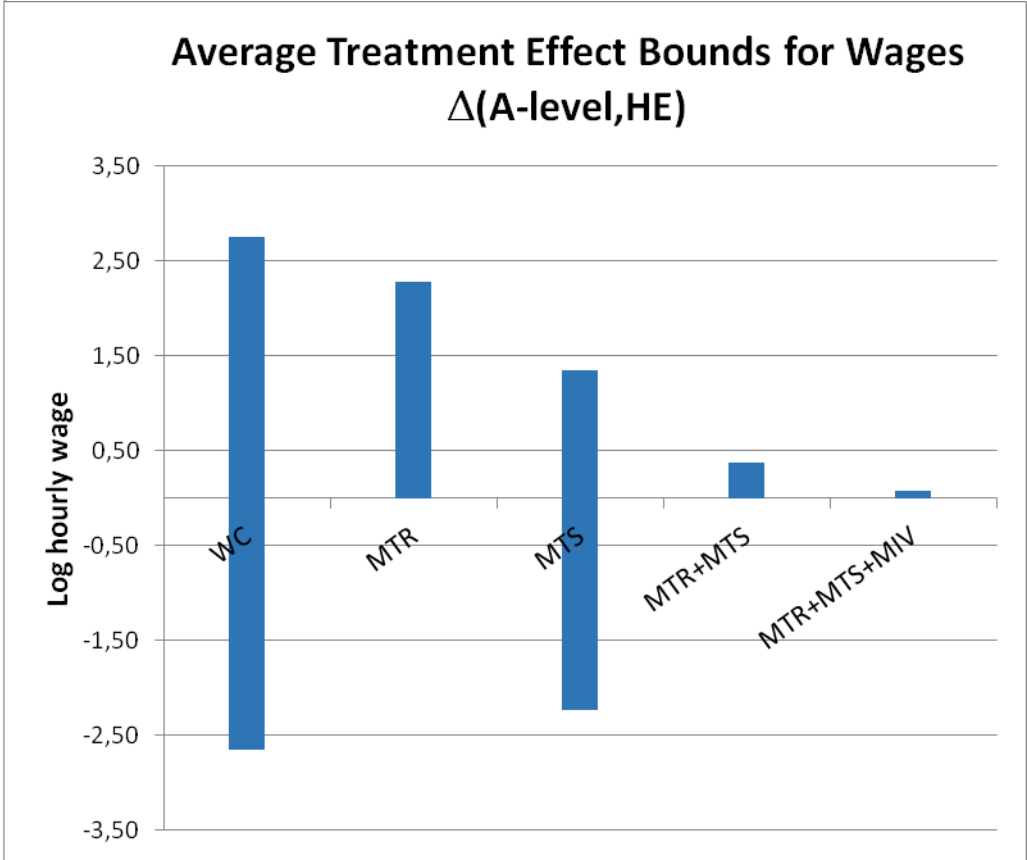
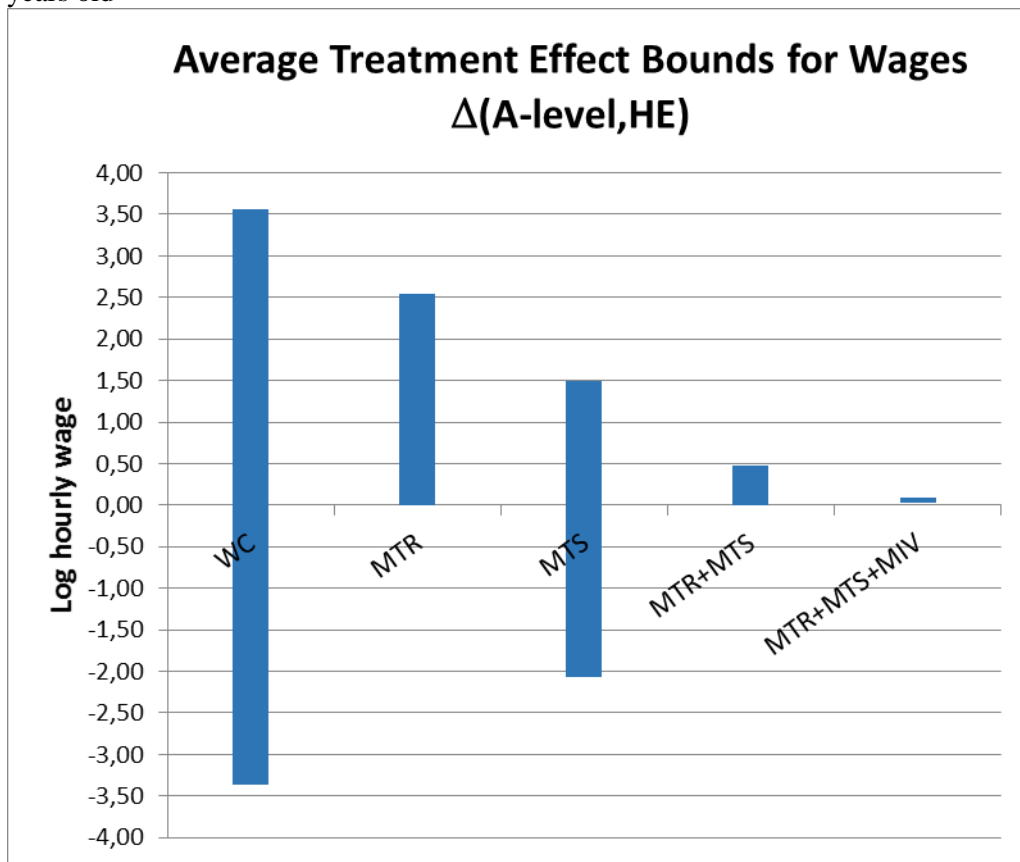


Figure 2.4: Wages as a function of Qualifications levels: bounds for (A-level, HE) – NCDS Women 42 years old



## **Chapter 3: The short and long term effects of an Educational Funding Reform on Regional Inequality in Brazil**

### **3.1 Introduction**

Public policies in education have usually focuses on expanding the quantity of education with less attention paid to quality. Debates about how to improve the quality of public education often focus on whether governments should increase their spending per pupil or reduce class size. The effects of school resources on students' outcome are rather controversial since there is no consensus in the literature about whether increasing school resources improves student achievement. This chapter aims to contribute to this literature evaluating a policy that increased funding per students in Brazil.

As in other developing countries, education policies in Brazil have in the last decades, largely focused on increasing primary and secondary school enrolment rates, with the final goal of achieving higher levels of educational attainment. More recently, however, the main concern has become the quality of education. One could argue that the development of cognitive abilities provided by the educational process depends crucially on the quality of education that one receives. Thereby, it is essential that an increase in school access to be accompanied by efforts to improve quality.

Little is known about how effective expenditures are at increasing pupil's performance and attainment. A crucial policy matter is, therefore, whether an increase in per pupil expenditure is able to improve students' outcomes. There is a large and controversial literature analysing the relationship between educational expenditures and student's achievement, both in developing and developed countries. In a review of the literature, Hanushek (2006) found no significant relationship between school resources and student performance. Glewwe *et. al* (2011) gives an overview of the literature for developing countries of the effects of schools' and teachers' characteristics on student attainment and found very mixed results. Holmlund et all (2010) and Gibbons et all (2012) found positive effects in schools resources on pupils achievement for the UK. Leuven et all (2007) on the other hand found no effects and even some negative estimates of additional school resources on students' performance in the Netherlands. The key question is, thus, whether higher spending translates into student achievements. Identifying the impacts of a higher per pupil

spending on educational performance is crucial since it is directly related to the formulation of efficient public policies within the realm of limited resources.

Brazil is commonly known for its cross region income inequality. Such regional disparity is also observed for education inputs and outputs. These disparities were mainly created by policies that left education funding largely to the local authorities. As richer States and municipalities have more capacity to invest in public education and attract better teachers, differences in public education structure between rich and poor regions are striking. These differences can be seen in terms of schools inputs, such as libraries, computers, qualified teachers; and school outputs, such as drop-out rates, test scores, years of schooling and so on. In fact the discrepancy in education achievement is mainly responsible for the large income inequality that takes place between and within regions (Reis and Paes de Barros, 1990).

In 1998, Brazil implemented an education funding reform called FUNDEF (Fundo de Manutenção e Desenvolvimento do Ensino Fundamental e Valorização do Magistério). The policy established, among other things, a minimum level of resources to be spent exclusively on the primary education system. Post reform, states and municipalities had to spend 15% of their total revenue exclusively on the maintenance and development of primary education.<sup>22</sup> The program also established a minimum amount of spending per pupil and required that at least 60% of FUNDEF allocations had to be spent on teacher's wages. In 2007, the policy was expanded, changing its name to FUNDEB (Fundo de Manutenção e Desenvolvimento da Educação Básica e de Valorização dos Profissionais da Educação) and incorporated other levels of the educational system, such as pre school and secondary education. Moreover, it also increased the fraction of total public revenues allocated exclusively on the maintenance and development of public education (pre school, primary and secondary educations): from 15% in 2006 to 16.67% in 2007, 18.33% in 2008, and 20% in 2009 onwards.

The reform changed the structure of public education funding and was responsible for a large increase in education spending.<sup>23</sup> One of the major goals of the reform was to reduce the large disparities within and across states, with the ultimate goal of reducing inequalities in terms of students' achievements. The program also aimed at increasing school quality, by

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<sup>22</sup> These expenditures include expenses related to the acquisition, maintenance and operation of facilities and the equipment necessary for teaching, use and maintenance of goods and services, payment and training of education's professionals, purchase of textbooks, school transport, among others.

<sup>23</sup> According to the World Bank (2010), FUNDEF/FUNDEB was responsible for a significant increase in education spending in Brazil since 1998, both in real terms and as a share of GDP. Gordon and Vegas (2005) showed that educational expenditure in all regions increased in the 1996-2002 period.

improving school inputs such as schools' infrastructure and teacher qualifications since FUNDEF/FUNDEB resources were also intended to improve teachers training.

Indeed, FUNDEF/FUNDEB policy is one of the largest educational reforms ever implemented in the country. This study thus explores the large increase in the amount of resources intended to education brought by the reform. This study has two main goals. The first one is to analyse whether the increase in education expenditures brought by the reform reduced inequality in terms of schools resources between poor and rich areas. We estimate whether FUNDEF program had an impact on school quality by exploring variations in revenues received by municipalities. School quality inputs are analyzed in terms of schools infrastructure and teachers characteristics. The second one is to assess whether the increase in the availability of resources to schools translated into higher student performance. The idea is to assess both the short term effects, by analysing students' test scores, and also somewhat longer term effects, such as the impact on education attainment.

The identification strategy explores the fact that the intensity of the reform varied by municipality. There was a substantial variation in program intensity across the country since poor municipalities with high levels of enrolments benefited the most. There were also some variations in the intensity of the reform within years as the amount received by a given municipality could also vary from year to year. The identification strategy explores these cross time within municipality and cross municipality within-time variations.

FUNDEF/FUNDEB resources were distributed among States and municipalities according to the relative enrolments in the previous year. As municipalities with higher number of students enrolled in their educational system receive more resources from the fund, they could manipulate their enrolment figures in order to receive a larger share of resources. To reduce this potential endogeneity problem in our variable of interest, an instrument for the observed revenue received from the program by municipalities was constructed.

This work contributes to the evaluation of the effects of one of the major educational policies ever implemented in Brazil. The regional approach and the analysis of the different effects between rich and poor areas, not yet explored in studies about the FUNDEF/FUNDEB, should be the subject of an extensive discussion, since education disparities are one of the major causes of the large income inequality across the country. This study also contributes for the evaluation of FUNDEF somewhat long term impacts which, as far as we are concerned, has not been explored yet. The comprehension of the effects of the



reform on largely diverse Brazilian regions is crucial to identify the strengths and weaknesses of the program and to contribute for the adoption of policies that are more sensitive to local realities.

The remainder of this paper is organized as follows. The next section describes the FUNDEF/FUNDEB Program. Section 3.3 reviews some of the literature. Section 3.4 briefly describes the background of the Brazilian educational system. Section 3.5 brings the empirical strategy adopted and the identification problem arising from the evaluation of the effects of the reform on schools inputs and student's achievement. Data are described in section 3.6, while Section 3.7 presents the main results of the chapter. Finally, section 3.8 summarizes and concludes.

### **3.2 The FUNDEF Program**

FUNDEF was created in 1997 and implemented in all Brazilian States by January 1998. The program changed the structure of public education funding in Brazil. Before the program, the 1988 National Constitution had established that 25% of States and municipalities' total revenue and 18% of the Federal Government's total revenue would have to be spent on their respective public educational systems. The 1988 National Constitution increased the amount of resources allocated to education, but it also increased the heterogeneity of public schools within and across States. In fact, this rule implemented in 1988 ended up transmitting the country's economic disparities to the educational system. Moreover, there was no mechanism to guarantee that resources were actually being spent on items directly related to education (Menezes-Filho and Pazello, 2007).

The FUNDEF program maintained the educational expenditure levels at 25% of all taxes and transfers, but required States and municipalities to spend 15% of their total revenue exclusively on the maintenance and development of primary education. However, instead of being directly applied in the different government levels, resources were directed to a common State fund, being lately reallocated to States and municipalities according to the number of students enrolled in the previous year in their respective educational systems. The program also established a minimum amount of spending per pupil. The Federal Government complements funds in cases where the minimum spending levels in the state is not achieved. Moreover, 60% of FUNDEF allocations had to be spent on teacher's wages.

For example, suppose that a municipality had R\$100 in total revenues (from tax and transfers). According to the 1988 constitution, the municipality had to spend R\$25 on education with resources allowed to be spent according to its preferences. After the FUNDEF program was introduced, the municipality had to donate R\$15 to a common State fund. The amount received back from the fund would depend on the number of pupils enrolled in its primary education. If the municipality's share of total pupils was equivalent to its share of total resources, then it would receive the same R\$15 back. Moreover, at least R\$9 (60% of R\$15) had to be spent on primary school teachers' wages. Suppose now that the Federal Government established a minimum spending per pupil of R\$1. Suppose further that a municipality had 15 students enrolled in its primary education - so  $R\$1 \times 15 = R\$15$ . However, if the municipality had 20 students enrolled in its primary education then it would receive an additional R\$5 from the federal fund.

In 2007, the policy was renamed FUNDEB, and gradually increased the fraction of total public revenues allocated to the fund: from 15% in 2006 to 16.67% in 2007, 18.33% in 2008, and 20% in 2009 onwards. FUNDEB also incorporated other levels of the educational system, such as preschool and secondary education.

Another change brought by FUNDEB regards the Federal Government's role. From 2007 on, the Federal Government, contribution to the fund became mandatory. Its contribution have also increased from 2007 (R\$ 2 billion in 2007 to R\$ 4.5 billion in 2009). The contribution was then set up at 10% of the sum of all States' funds from 2010 onwards. The Federal resources are distributed among States by giving priority to the ones with the lower levels of spending per pupil.

FUNDEF(B) dramatically changed the structure of funding of the educational public system in Brazil. One of the aims of the reform was to reduce the disparities in the allocation of resources within and among regions. Besides, by increasing the amount of resources allocated to public schools the reform also aimed at improving the quality of basic education. As schools would now have more resources to spend not only on teacher salaries, but also on other school inputs such as libraries and computers.

Figure 3.1 presents education expenditures per pupil as a share of GDP per capita. These data refer to consolidated investments in education by the Federal Government, States and the Federal District and municipalities. The figure shows an increase in the share of resources destined to primary education during the period. Despite the great increase in the

GDP per capita during 2000-2011, there was a clear rise on the proportion of expenditures spent in primary education.<sup>24</sup> Thus, the increase on spending per pupil observed in the period was not only due the economic growth but was clearly associated to an increase on the proportion of the resources destined to education.

Figure 3.2 presents the evolution of municipal expenditures on education as a share of municipal GDP during the 1997-2011 period.<sup>25</sup> The figure shows a clear increase in education expenditures during the period. The poorest regions (North and Northeast) have spent a higher share of their GDP on education, which is quite a desirable result. The Figure also shows a peak in 1998 when FUNDEF was first implemented. Again, the figure also shows an increase in municipal spending in education as a share of GDP.

Figure 3.3 presents municipal real spending per pupil by region.<sup>26</sup> Despite an increase in the share of educational expenditures per GDP by the municipalities located on the poorest regions of the country, their spending per pupil actually remains lower than in municipalities located in richer regions. The Figure also shows a great deal of inequality in expenditure per pupil across regions in Brazil. Even with increases in education spending, the North and Northeast, historically the poorest regions in Brazil, have the lowest levels of per pupil spending during the whole period. The richest regions, South and Southeast, spent around R\$4.000 per pupil in 2011, while the poorest ones spent around 50% of this amount. There is also a significant variation on per pupil spending between years.

More important than knowing that there was an increase in education expenditures, one should ask what this expenditure figures would actually look like if there had been no reform. Figures 3.4 and 3.5 show spending on education by percentile of GDP per capita. The figures illustrate what would be the total municipal spending on education in the "absence" of reform. In order to do this, the total expenditure on education was simply subtracted from the net amount of resources received by the municipalities from the fund. Thus, municipalities in

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<sup>24</sup> Real GDP per capita in Brazil grew around 30% during the 2000-2011 period (IPEADATA), while real expenditure per pupil on primary education grew almost 170% in the period (INEP).

<sup>25</sup> Unfortunately, the latest information available on municipal GDP - prior to 1997 - is for 1985, but there is no information on municipal spending on education for this year. It is also important to note that the "spending on education" variable refers to all education levels and not only to primary education. Nonetheless, as the vast majority of students in municipalities are in primary schools, the variable represents well the evolution on primary education spending.

<sup>26</sup> From 1995 to 2001, expenditures in education and culture were available only in aggregated terms. However, around 95% of the total spending were directed to education. Again the "municipal spending on education" variable refers to all education levels.

which the contribution to the fund was simply equal to what they have received from it, had no “real” gain from FUNDEF. For municipalities that lost resources to the fund (contributions higher than the funds received) we suppose that there was neither a gain nor a loss. Since rich municipalities were still able to reach the spending goal established even losing resources to the fund.

Figure 3.4 shows education spending per pupil (with and without the reform) for municipalities in the top quartile of GDP per capita. The difference on education spending becomes more significant only from 2006 on. This is due the fact that in the initial years of the reform the vast majority of these municipalities either did not gain any resource from the fund or actually lost resources to it. However, expenditures without FUNDEF policy may actually be overestimated, since it was assumed that these municipalities had actually spent all their contribution to the fund on their education systems. Figure 3.5, on the other hand, shows education spending per pupil with and without the reform for municipalities in the bottom quartile of the GDP per capita. The Figure displays a remarkable feature: the actual education spending for the poorest municipalities would have been much lower without the reform, especially after 2006, when the reform not only incorporated other education systems but also gradually increased the resources allocated to education. As before, education spending without the reform might be actually being overestimated so the differences presented may actually be greater.

### **3.3 Literature Review**

There is a large and somewhat controversial literature analysing the relationship between school resources and student’s achievement. Discussions about school expenditures began with the pioneering work by Coleman et al. (1966). Notwithstanding the substantial research in recent years, as shown in Hanushek (2006) and Hanushek and Rivkin (2006), there still a lack of a clear consensus on the impact of specific education policies on student learning.

In a review of the literature, Hanushek (1997, 2003) argued that there is no significant relationship between school resources and student performance. Analysing 376 estimates of education production functions for developed countries, Hanushek (2003) found that, for the most of them, there was no relation between schools inputs and educational performance. In terms of teacher-pupil ratio, only 14% of the estimates found positive and statistically

significant effects on student performance.<sup>27</sup> However, another 14% of the estimates showed a negative and statistically significant effect. Moreover, the vast majority of the estimates (72%) found no significant effects.

Krueger (2003), however, contradicts these findings. According to the author, Hanushek's analysis applies equal weights to every estimate and therefore studies with a higher number of estimates were assigned much more weights than others. Moreover, these studies often rely on small samples and misspecified models. Assigning equal weights to each study analysed, Krueger found that the literature actually showed a systematic link between class size and student achievement.

Glewwe et. al (2011) reviewed the literature of the effects of schools' and teachers' characteristics on student attainment and learning. Analysing studies from 1999 to 2010 for developing countries, the authors found that, despite the increase in the number and quality of the literature, little is known about the impact of education policies on student outcomes. The authors suggest two possible reasons. Firstly, the same policy could have quite different effects across countries and even within countries. Second, much of the literature has centred their attention on basic school and teacher characteristics. However, the way in which schools are organized and their interactions may matter the most.

Analysing studies for class sizes in developing countries, Glewwe et. al (2011) verified that, in general, larger class sizes have negative impacts on student learning. However, 9 out of 29 studies (30%) showed a significant and positive. Considering only the sample of high quality studies, the authors found that, in overall, the estimates suggested a negative impact of class sizes on student learning. However, the results are not as decisive, since five studies found significantly negative effects, while three studies found a positive and significant effect. The authors also review the literature on the effects of schools' inputs on daily attendance of students, current enrolment, and years in school. Considering 14 high quality studies, the authors find that building new schools increases enrolment and years of completed schooling. Other school inputs such as teacher's qualification and characteristics of the schools showed very mixed results.

Guryan (2001), using a regression discontinuity design to analyse a policy that is similar to the FUNDEF reform; The Massachusetts Education Reform Act (MERA) aimed at

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<sup>27</sup> 276 estimates

decreasing within-state inequality in per-pupil spending by increasing the amount of resources to districts that historically have spent less on schools. Guryan found a positive effect of education spending on test scores. The estimates suggests that a one standard deviation increase in per-pupil spending (\$1,000) increases math, reading and science test scores by around half of a standard deviation for 4<sup>th</sup> graders.

Card and Payne (2002) evaluate the effects of school finance reforms in the US on students' performance. They found that the reforms narrowed the spending gap between poorer and richer districts and that reduction in spending inequality also reduced the gap on test scores within children from different backgrounds.

Holmlund et al (2010) analyse the effects of an increase on school expenditures in the UK on student's achievement. School expenditures in the UK increased in real terms after 2000 after many years of stagnation. The results show a positive effect of school expenditures on national tests taken at the end of primary school. The results also show evidence of a greater effect for students from economically disadvantaged backgrounds.

Gibbons et al (2012) also using data for the UK explore the fact that similar schools close to Local Authority boundaries end up receiving different levels of funding to estimate the effect of school funding on pupil performance. The results show that the differences in funding levels were associated with sizable differentials in pupil attainment in urban schools.

Machin et al (2010) analyse an UK educational policy, which gave extra resources to schools – the Excellence in Cities Programme. According to the results, the policy was effective at improving Mathematics achievement and school attendance. The policy had a larger effect on more disadvantaged schools and on the performance of middle and high ability students within these schools, showing however little or no effect on low ability students.

Leuven et al (2007) evaluate the effect of two subsidies targeted at disadvantaged pupils in the Netherlands. The subsidies provide extra resources to schools to improve teacher's condition and to acquire computer and software. The estimates show no significant effects for the teachers' subsidy and even some negative effects for the computer subsidy on students' achievement.

Van der Klaauw (2008) evaluates the US Title I program which provides financial assistance for the expansion and improvement of instructional programs on schools with high concentrations of poverty. The estimates suggested that the program had no effect on improving student outcomes in high-poverty schools in New York City.

In the context of FUNDEF, previous studies have analysed the effects of the reform on some aspects of the Brazilian educational system. De Mello and Hoppe (2005) using state- and municipality-level data during 1991-2002, found that FUNDEF contributed to the fast increase in net enrolment rates in primary education, especially in small municipalities.

Gordon and Vegas (2005) showed FUNDEF revenues have indeed translated into education spending. Employing School Census data from 1996 to 2002 the results show that the program had a large effect on increasing enrolment rate in municipalities where spending per pupil was below the new minimum established by the law. They also presented some evidence on class size reductions and teachers' qualifications, which have also contributed to the reduction of age/grade distortion. Finally, they found a weak link between mean spending and student achievement.

Also employing Brazilian School Census data, Estevan (2009) showed that, FUNDEF was associated with a decrease in the share of private primary school enrolment, especially for the grade one. The study also showed that the reform improved some quality indicators at the school level, such as teacher's qualification and infrastructure. According to the author, quality improvements brought by the reform may explain the decrease in the share primary enrolment in private schools.

Anuatti et al. (2003) point out for positive effect of the program on public school teachers' salaries. The program seems to benefit the most teachers from municipal schools located in smaller cities and poorer regions. Additionally, Menezes-Filho and Pazello (2007) investigated the impact of FUNDEF reform on teachers' relative wages and students' test scores. The authors explore the fact that wages in public schools were changed exogenously by FUNDEF reform to identify the impact of teachers' wages on the students' outcomes. Using data from SAEB (Sistema de Avaliação do Ensino Básico) for 1997 and 1999 for students at the 8<sup>th</sup> grade and a difference and difference strategy, they found an effect of reform on teacher's salaries, and a positive effect of the latter on students' performance (about half standard deviation).

Franco and Menezes-Filho (2010) applying a difference in difference approach and using School Census from 1997 to 2005, found that FUNDEF increased enrolment rates and the number of teachers in primary education. The program also had a positive effect on the proportion of teachers with higher education in the upper primary system. The results also show some evidence of positive effect on student's approval rate and a negative effect on the drop-out rates.

Andrade et al. (2009) using School Census data for 1997 and 1999, before and after FUNDEF implementation, and employing a difference and difference approach analyse whether the introduction of FUNDEF reform influenced teachers' behaviour in public schools. The author argue that FUNDEF reform generated incentives for teachers to increase students' fail rate and consequently their salaries, since FUNDEF resources were directly proportional to the relative number of students enrolled in public schools in states and municipalities. The results suggested that public school's teachers engaged in this opportunistic behaviour in order to affect the number of students enrolled in their schools when compared to teachers from private schools. This behaviour however varied in intensity depending on the number of schools in the municipality or state. When there are many schools, teachers have a lower incentive to influence the fail rate in one school since his/her behaviour has a negligible effect on the amount of resources received by the municipality where their schools are located.

For the Brazilian context, few studies have tried to link school quality and later outcomes like education attainment, employment, or earnings. Behrman and Birdsall (1983), using a State-level measure for teacher quality, examine the impact of school quality on educational returns and earnings. The inclusion of the school quality variable sharply reduces the estimated rate of return to years of schooling. School quality increase has a strong and positive effect on earnings level through its impact on the rate of return to education.

Curi and Menezes-Filho (2006) examine the relationship between test scores and wages of a young cohort of Brazilians workers. Using pseudo panel model, the authors followed two cohorts born in 1977-78 and 1987-88, in three stages of life: childhood (4-5 years old), school (17-18 years) and the labor market (23-24 years). The results show a positive relationship between the performance on proficiency exams and future earnings.



It should be noted that Gordon and Vegas (2005) is the only study that somehow brings the regional inequality issue to the fore. As far as we are concerned, there is no other work that broadly overlooks the program main objective: the reduction of inequality in schools inputs and especially in outputs within and between regions in Brazil. This is a gap in the literature that this paper aims to cover. Moreover none of the papers above have applied the empirical approach employed in this study, which is less subject to endogeneity problems.

### **3.4 Backgrounds of the Brazilian Educational System**

Brazil is composed of 26 States plus a Federal District, and has 5,565 autonomous municipalities. Public schools are run by different government's levels: the Federal Government, the State Government and Municipalities. The vast majority of schools are run by the latter two.

The Brazilian educational system is divided into the following cycles: pre-school education - 0 to 5 years old students; lower primary education - grades 1 to 4 (consisting of four years); upper primary education - grades 5 to 9 (five years); secondary education (3 years); college (four or five years)<sup>28</sup>. Each level of government is responsible for a given cycle. Municipalities are mainly responsible for the provision and management of pre-school and primary education. States' governments are usually in charge of primary and secondary education, whereas the Federal Government is responsible for college education. Municipalities, however, play the largest role in public primary education: around 83% of primary students were enrolled in municipals school in 2007 (School Census, 2007). Municipals schools are funded mainly by local transfers and taxes and are usually run by the local governments.

In 1990 in Brazil, less than 40% of school age children completed the 8<sup>th</sup> grade of primary school, compared with 70% in the Latin American region (95% for the OECD). Over 70% of children in Argentina and Chile were enrolled in secondary education (91% across OECD), while this figure was only 38% in Brazil. The average schooling for the adult population was 3.8 years, a figure well below the average for other Latin American countries (around 8 years in Argentina and Chile and 8.9 years in the OECD) (World Bank, 2010). In the last decades, however, Brazil has observed large improvements in educational attainment. Table 3.1 shows the average years of schooling for the adult population between 1960 and

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<sup>28</sup> In 2006, Brazil adopted a legislation extending the length of compulsory schooling by one year and creating a primary cycle with 9 years. The new entry age to primary school changed from 7 to 6 years.

2010 for selected countries. Despite Brazil having the lowest level of school attainment in 2010 (7.3 years), it presented the fastest rate of increase in educational attainment between 1990/2010.

In the last decades, Brazilian investment in education has largely focused on increasing primary and secondary school enrolment rates. In 1980, the net enrolment rate in primary education was 64%. This rate rose to 86% in 1991 and reached 100% in 2003, indicating that virtually all children between 7-14 years were at school (Riggoto and Souza, 2005).<sup>29</sup> According to PNAD (Pesquisa Nacional de Amostra por Domicílios), the net enrolment rate in secondary education has also rose from 18% in 1991 to around 52% in 2010.

Figure 3.6 shows the evolution of the net and gross enrolment rate for primary education. From 1998 onwards the net enrolment rate was always above 90%, reaching almost 95%, meaning a high number of children enrolled at the appropriate grade level. There was also a decrease on the gross enrolment rate from 2000, which reflects a reduction of age/grade distortion.<sup>30</sup>

Nonetheless, despite the improvement observed in the number of students covered by the educational system, the quality of education offered by public schools and, therefore, its student's performance is still an issue. SAEB (Sistema de Avaliação da Educação Básica) evaluates students from the 4<sup>th</sup> and 8<sup>th</sup> grades of primary education and also 3<sup>rd</sup> year students from secondary education on reading and math tests. The results for the 2003 evaluation showed that 55% of the students in 4<sup>th</sup> grade were concentrated in the very critical and critical stages of proficiency in reading. In the North and Northeast regions (poorest regions of the country), this figure reached 70% and 66% respectively, while for the Southeast and South (richest regions) the figures were 44% and 47% respectively. For the math test, 52% of the students in 4<sup>th</sup> grade were concentrated in the very critical and critical stages of proficiency. In reading, this indicates an inability to understand short and simple texts. In mathematics, the 'very critical' and 'critical' levels gather students who cannot solve simple problems

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<sup>29</sup> However, this universal enrolment in primary education does not translate into students graduating in the equivalent proportions. In 2000, only 44% of enrolled students were able to finish this level of education. Among students who complete primary education, only 72% go on to high school.

<sup>30</sup> The net and gross enrolment rates presented in the figure are for public and private schools. However, for private schools both rates were quite constant during the period.

formulated from everyday situations involving addition or subtraction of natural numbers (INPEP, 2005).

These results are much in line with the ones found by the Programme for International Student Assessment (PISA). Over the past decade, the tests offered by PISA have allowed countries to track students' performance. Figures 3.7 and 3.8 show the percentage of students below the proficiency level 2 in reading and math in PISA standardised test scores.<sup>31</sup> Figure 3.7 shows that around 50% of the Brazilian students are below proficiency level 2 in reading. From Figure 3.8, 70% of Brazilian students in 2009 were below proficiency level 2 in math. Thus, the majority of students in Brazil are classified in the category of “lowest performers - lacking basic skills”. However, while some knowledge has been gathered on how to improve school access, little is known about cost-effective policies that improve quality.

### **3.5 Empirical Strategy**

Since the changes in policy rules were common to all municipalities from 1998 onwards, one can consider that the only source of variation promoted by FUNDEF was the amount of resources received by the municipalities from the fund, since; poor municipalities with higher levels of primary school enrolment were the principal beneficiaries of the reform.<sup>32</sup>

Therefore, our first purpose is to estimate whether FUNDEF program had an impact on school quality by exploring variations in revenues received by the municipalities from the fund. School quality inputs were analyzed in terms of schools infrastructure; some measures of school's basic infrastructure are considered such as share of schools with electricity, running water, sewage, principal office, and toilet inside the building. Other related infrastructure measures are also included: the share of schools with a library, computer lab, science lab and sport facilities and teacher quality measures such as the proportion of teachers with a degree and pupil-teacher ratio. Here we focus only on municipal schools and primary education, since this cycle was the first affected by the policy and the vast majority of primary students are enrolled in municipal schools.

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<sup>31</sup> Students below proficiency Level 2 are considered the lowest performers, since basic skills in reading and math are considered lacking. The proficiency levels range from 1 to 6, being 6 classified as the top performers (OECD, 2009).

<sup>32</sup> For now on FUNDEF and FUNDEB are going to be used interchangeably.

$$y_{jt} = \beta F_{jt} + \alpha X_{jt} + d_t + m_j + n_{jt} + u_{jt} \quad (1)$$

Where  $y_{jt}$  is the outcome of interest in municipality  $j$  in year  $t$ ;  $F_{jt}$  denotes the amount of resources received from the fund for municipality  $j$  at year  $t$  by the population between 7 to 15 years old ;  $d_t$  is a year fixed effect;  $m_j$  is a municipality fixed effect;  $n_{jt}$  is a municipality specific time trend;  $X_{jt}$  represents the controls variables and  $u_{jt}$  denotes the random error.

Our main objective is to estimate the effects of the program on the reduction of school's inequalities between and within regions. Given that, we estimate:

$$y_{jt} = \beta F_{jt} + \delta(F_{jt} * g_{jt}) + \gamma g_{jt} + \alpha X_{jt} + d_t + m_j + n_{jt} + u_{jt} \quad (2)$$

where  $g_{jt}$  is the municipality average per capita income in year  $t$ , which measures whether FUNDEF's revenue had a different impact on poor and rich municipalities. We expect a larger effect on the poorest regions as they were mainly net receivers. Control variables include total population, age 7-15 population, municipal GDP per capita and other municipal transfers and revenues. The latter was introduced given it is potentially correlated to FUNDEF resources. Regressions are weighted by municipality size to take into account that improving outcome in a bigger municipality is more important than improving it in a small one. Moreover, if the reform has mostly affected small municipalities then it has a small impact on the overall population, which should be reflected in the weights. Robust standard errors clustered by municipality-year are computed.

Another important issue is how to measure the impact of the FUNDEF reform in a given municipality. The first solution, is simply to use the amount received from the State fund by each municipality ( $F_{jt}$  in equation (1,2)). Another possibility is to use, the difference between the contribution to the fund and the revenue received from it, which is shown below. The impact of the reform varied depending on the difference between what a municipality has paid to and received from the fund. For example, if the revenue received from FUNDEF by a given municipality is close to its contribution, the impact of the reform on this municipality is virtually zero. On the other hand, if a municipality receives a substantial amount from the fund compared to its contribution, the impact of the reform would be large. Thus, an indicator

that measures the intensity of the impact of the reform in each municipality is constructed as follows.

$$IntensityFundef_{j,t} = \frac{E_{j,t-1}(Fundef_{j,t}) + Federal_{j,t} - 15\%taxes_{j,t}}{15\%taxes_{j,t}} = \frac{Received\ from\ FUNDEF_{j,t} - Contributed\ to\ FUNDEF_{j,t}}{Contributed\ to\ FUNDEF_{j,t}} \quad (3)$$

Where the amount received from the fund by the municipality  $j$  in year  $t$  depends on the number of students enrolled in the municipal system  $E_{j,t-1}$  in year  $t-1$ , plus the amount of resources received from the federal government. The municipal contribution to FUNDEF is equal to 15% of municipalities' taxes and transfers.

Considering that, we also estimate a model as

$$y_{jt} = \beta I_{jt} + \alpha X_{jt} + d_t + m_j + n_{jt} + u_{jt} \quad (4)$$

where  $I_{jt}$  measures FUNDEF intensity given by (3)

Figure 3.9 illustrates the distribution of the intensity of the FUNDEF reform by region. It is worth noting that the FUNDEF reform had a quite significant impact on the poorest regions. Most municipalities in the North and Northeast regions were net resource receivers and some of them received up to six times the amount of their contribution. For the richer regions (Southeast, South and Center-West) the mode is around zero, meaning that most of their municipalities contributed with a similar amount from what was received from the fund.

Figure 3.10 displays the distribution of the FUNDEF intensity by percentile of municipal income per capita. The Figure shows that municipalities in the bottom percentile (number 1) were the most affected by the reform as the distribution is highly skewed to the right. For the municipalities on the top percentile the mode is centred on zero.

Moreover, Figures 3.9 and 3.10 show that not all municipalities were positively affected by the reform since some of them were in fact net contributors. This is mainly true for richer municipalities. For some of them the amount of resources allocated to the fund

(15% of all transfers and taxes) were in fact higher than the amount that they would have received given FUNDEF rules. Therefore, there was a substantial variation in the exposure to the program across the country, since poor municipalities with high levels of enrolments benefited the most. Thus, in order to try to recover FUNDEF effects on schools inputs and outputs, our identification strategy explores this variation in terms of resources.

The second objective of this study is to evaluate whether the increase in the funding provided by the reform translated into an improvement in students' performance. More formally, the following equation is specified:

$$y_{isjt} = \beta F_{jt} + \gamma g_{jt} + \alpha X_{isjt} + \phi W_{jt} + d_t + m_j + u_{jt} \quad (5)$$

where  $y_{isjt}$  is the proficiency of student  $i$  in school  $s$  in municipality  $j$  at year  $t$ ; the  $X$  vector contains student's race, gender, age, a dummy variable for whether the student has failed before, mother's education, if the student works, dropped-out before, school entry age, a measure of the economic situation of the student (measured in terms of number of bedrooms in the house, number of bathrooms, number of cars his family has, if the family has a computer) and whether the school has adopted a cycle regime instead of the conventional grade regime.<sup>33</sup> We also control for some municipal characteristics such as: the size of population between 7 to 15 years, the municipality GDP per capita, child mortality rate, illiteracy rate, share of people over 25 with a degree, share of children vulnerable to poverty, unemployment rate - 18 years or more -, percentage of population living in households with a toilet and running water, percentage of population living in households with electricity, percentage of population living in households with inadequate water supply and sanitation and percentage of householders mothers without primary education and with at least one child younger than 15.<sup>34</sup> It is important to control for all these municipalities' characteristics since students from areas with better social economic conditions might also have a better education environment. Estimates were not controlled for school characteristics since, in principle, all of them were affected by the reform (excepted for the cycle/grade regime that is not related to the reform).

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<sup>33</sup> More about this policy on the next section.

<sup>34</sup> The variable "share of children vulnerable to poverty" is measured as the proportion of individuals' with 14 years old or less which household income per capita is equal or less 1/2 of the minimum wage.

The impact of the reform on students test scores was not only contemporaneous but also a result of the years attending a public school with better resources (a cumulative effect). The data allow us to observe how many times a municipality were treated during the 1998-2011 period. Estimates were then computed for both the contemporaneous and cumulative effects

We also explore the impact of the funding reform on intermediate and somewhat long term outcomes. The effects are analysed in terms of the probability to complete primary education, to complete secondary education, probability to attend high school, and in terms of completed years of schooling. More formally:

$$y_{ist} = \beta F_{st} + \delta(F_{st} * g_{st}) + \gamma X_{ist} + \theta W_{st} + d_t + t_s + v_{st} + u_{st} \quad (6)$$

Where  $y_{ist}$  is the outcome of individual  $i$  in State  $s$  at year  $t$ ;  $g_{st}$  is the State average per capita income in year  $t$ . The coefficient of interest is then  $\delta$  which measures the effect of the policy on the most affected States after 1998;  $d_t$  is a year fixed effect and  $t_s$  is the State fixed effects and  $v_{st}$  is a State specified trend. The X vector contains individual's race, gender, age, a dummy variable for whether the person lives with his mother, mother's education, a dummy variable for work, household income per capita, and length of primary education (8 or 9 years). Some State controls ( $W$ ) are also included such as the proportion of poor and extremely poor (as well an interacted term with a dummy for observations post 2001, year when Bolsa Escola/Bolsa Familia was implemented), the proportion of public schools which adopted the cycle regime, State GDP per capita, population aged 6 to 18.

### 3.5.1 The Identification Problem

An identification issue could arise in equations (1) to (6) if the reform is correlated with unobserved factors that also affect school indicators. This could happen if the resources received from the fund are not exogenous. The amount received depends on the amount of tax revenues collected within a State and on the number of students enrolled in municipal schools in the previous year. All municipal taxes linked to the fund are in fact State or Federal taxes in which municipalities participate in. Moreover only the Federal and State governments set

collection and distribution rules. Therefore, municipalities have very little manipulation power over them.<sup>35</sup>

The endogeneity problem becomes more relevant with regard to the enrolment rates in each municipality. As municipalities with higher number of students enrolled in primary education receive more resources from the fund, they could manipulate their enrolment figures in order to receive a larger share of resources. This might introduce an endogeneity problem in our variable of interest. To deal with this issue, a variable was constructed simulating the revenues each municipality would receive in each year based on current taxes, FUNDEF's distribution rules and enrolment rates reported in the 1996 School Census.<sup>36,37</sup> So, the instrument depends on pre-law enrolment rates, on current Federal and State taxes, and on current FUNDEF's distribution rules (set by the Federal Government), which are exogenous to any particular municipality's primary investment. Moreover, to control for possible differences in municipalities' time trends regarding municipalities' initial enrolment figures in primary education, a linear time trend  $t$  was interacted with the fraction of population between 7-15 years old enrolled in public primary education.

The distribution coefficient below represents the share of each government entity to the amount of FUNDEF resources collected in each State. The coefficient is calculated as follow:

$$dc_{jst}^{FUNDEF_t}(enroll_{1996}) = \frac{\sum f_{ii}^j w_{ii} enroll_{j,s,1996,i}}{\sum \sum f_{ii}^j w_{ii} enroll_{j,s,1996,i} + \sum f_{ii}^s w_{ii} enroll_{s,1996,i}} \quad (7)$$

where  $j$  index municipality;  $s$  State,  $t$  year; so  $dc_{jst}^{FUNDEF_t}(enroll_{1996})$  represents the distribution coefficient for municipality  $j$  located in State  $s$  in year  $t$ ;  $i$  index education level;  $enroll_{j,s,1996,i}$  represents the number of enrolments in a given municipality in a given State for a given level of education in 1996;<sup>38</sup>  $w_{ii}$  is the weighting factor and  $f_{ii}$  represents the

<sup>35</sup> Federal and State Governments also have limited manipulation power over taxes. Federal Government have their tax rates and rules for collection and distribution specified by the Constitution. Some State taxes also have its minimum or maximum rates determined at the federal level.

<sup>36</sup> As the reform was first implemented in 1998 some municipalities could have inflated their enrolled rates in 1997 in a response to the new reform rules.

<sup>37</sup> Kosec (2011) employs a similar instrument to estimate the effects of the program on pre-primary related variables.

<sup>38</sup> Note that all enrolment rates are based on 1996 School Census.



percentage of enrolments in each education level considered.<sup>39</sup> The distribution coefficient is then multiplied by the total amount of resources collected by the fund in a given State and year, which results in the financial value received from the fund by each municipality, computed as follow:

$$Fundef_{jst} = dc_{jst} \cdot Total_{st} \quad (8)$$

Where  $Fundef_{jst}$  is the amount, based on 1996 enrolment, received from the fund by municipality  $j$  in State  $s$  in year  $t$ ; and  $Total_{st}$  is the total amount collected by the fund in State  $s$  in year  $t$ .

It shall be demonstrated in the next section that the instruments are correlated with observed per capita revenue and with its interactions with per capita income. The instruments are built based on pre-law enrolment rates, current Federal and State taxes, and on FUNDEF's distribution rules, which are exogenous to any particular municipality's primary investment. Given that we assume that the exclusion restriction holds, in another words, that simulated per capita revenues and its interactions are exogenous at the municipal level.

It is not a simple task to explore all the effects that a reform of this scale may have had in the Brazilian public education. That is because other important changes also took place in the Brazilian educational system in the period. During the period analysed, some school systems adopted the so-called Progressão Continuada program. This program divides the educational system into cycles instead of grades. In addition to the conventional annual grade repetition regime a learning cycle regime was introduced in which students progress by cycles, of usually three grades, and not by school years. In the final year of a cycle students that do not meet the minimum requirements are retained. General Education Act of 1996 (Lei de Diretrizes e Bases da Educação Nacional: LDB) first allow the introduction of the new regime but, it was effectively implemented from 1998. The program however was not adopted by all Brazilian public schools and, the ones which adopted it did not follow a unique implementation schedule. Koppensteiner (2014) found a negative effect of the Progressão Continuada program on 4<sup>th</sup> grade students' test scores in the State of Minas Gerais. Menezes-Filhos (2008) showed evidence of higher promotion rate and a lower dropout rate for urban state schools that adopted the program. The estimates also showed a significant negative

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<sup>39</sup> The values for  $w_{it}$  and  $f_{it}$  are presented in Table A.1 and A.2 in the Appendix.

effect in proficiency of 8th grade students, whereas the impact for 4th grade students was not significant. To deal with the possible effects of Progressão Continuada program on our estimates, a control for whether the school has adopted the cycle regime is also included.

In 1996, Brazil established a minimum schooling requirement for kindergarten and lower primary education (1<sup>st</sup> to 4<sup>th</sup> years) teachers.<sup>40</sup> Teachers from this cycle should have at least secondary education. We assume, however, that this law does not affect the probability of completing a college degree.

Another important policy in Brazil during the period was the “decentralization” process of public schools. The decentralization is the total or partial transfer of primary education from States to municipalities. The FUNDEF reform created incentives for the decentralization as it provided the financial resources needed for such change. Since the decentralization process was only feasible because of the funding provided by the FUNDEF reform, some authors consider both reforms as a single wider one. This process could affect our empirical strategy in what regards the municipalities’ enrolment rates. However, our strategies dealing with the endogeneity of the enrolment rates should alleviate this concern.

Conditional cash transfer programs targeted to low income families was also an important policy implemented in period. Implemented in 2001, Bolsa Escola program transferred grants to poor families in order to enable them to invest adequately in their child’s schooling and health. From 2003, Bolsa Família unified all previous social programs such as Bolsa Escola and largely expanded the number of beneficiaries. In order to receive the grant, families have to keep their children at school. Children between 6 to 15 years old must have an attendance frequency of least 85%, while students from 16 and 17 years old must have an attendance frequency of at least 75%. Some studies have shown that Bolsa Familia has a positive impact on enrolments, attendance and grade progression for children from beneficiary families (Oliveira et al., 2007; Glewwe and Kassouf, 2011). In order to deal with Bolsa Familia effects we control for several individuals and municipalities’ poverty related variables.

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<sup>40</sup> Lei de Diretrizes e Bases da Educação de 1996, Artigo 62.

### 3.6 Data

Our empirical analyses combine several data sources. School information came from the Annual School Census available from the Ministry of Education. This survey is filled out at the school level and includes information on student enrolment, number of teachers, teachers' educational attainment, and school characteristics. The data also have information for public (Municipal, State, and Federal) and private schools. We focus only on municipal public schools, since they are the ones mainly responsible for providing primary education and, therefore, the most affected by the reform.<sup>41</sup>

A municipal level panel data from 1997 to 2010 is then constructed with several important aspects on primary education quality. Some measures of school's basic infrastructure are considered such as: share of schools with electricity, running water, sewage, principal office, and toilet inside the building. Other related infrastructure measures are also included: the share of schools with a library, computer lab, science lab and sport facilities in addition to teacher quality measures such as the proportion of teachers with a degree and pupil-teacher ratio. Given the high correlation, especially among the school infrastructure variables, a principal components analysis (PCA) was utilised to combine these variables into two infrastructure quality indices. Measures such as the share of schools with electricity, running water, sewage, principal office, and toilet inside the building were combined into an index of basic school infrastructure quality called Infrastructure I Quality Index. Moreover, measures such as the share of schools with a library, computer lab, science lab and sport facilities were combined into another index of infrastructure quality called Infrastructure II Quality Index. The first principal component from each of these PCAs was then used to construct the indexes. For both indexes and to all regions considered, the first principal component explains at least 50% of the variation of the variables.

Table 3.2 shows some descriptive statistics for the School Census data. Some school inputs such as the proportion of computer labs, sport facilities, and libraries have increased in the period; however, their levels are still very low. Some basic infrastructure items like access to running water, electricity, and toilet inside the school buildings have also increased during

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<sup>41</sup> Only schools which offer primary education were considered. We also exclude schools with less than ten students enrolled and which had no teacher in this level education.

the period. In 2010, around 62% of primary teachers had a college degree; Pupil teacher ratio has decreased by around 3 from 1997 to 2010.

The data set *Finanças do Brasil* (Finbra), consolidated by the Brazilian Federal Treasury, provides information on the amount of resources that each municipality contributed to and received from the fund. It also contains data on education expenditures, municipal revenues, and expenses as well as aggregated data for the States and Brazil as a whole. Information available from 1998 to 2010 was used in this study.<sup>42</sup>

Table 3.3 shows some summary statistics for the School Census data and municipality revenues by regions. The data shows a great deal of inequality in terms of schools inputs, especially between poorest (North and Northeast) and richest regions (South and Southeast). The North and Northeast regions have the highest revenue per capita and on average their municipalities received two times more than the amount they contributed to fund.

Annual municipality-level data on income per capita, population, and population-by-age are available from IPEADATA. Municipal data on child mortality rate, illiteracy rate, unemployment rate, and the covariates, such as the share of population with a higher degree, share of children vulnerable to poverty, the percentage of population living in households with a toilet and running water, the percentage of population living in households with electricity, the percentage of population living in households with inadequate water supply and sanitation, the percentage of householders mothers without primary education and at least with one child younger than 15 are available from the Atlas of Human Development in Brazil (*Atlas do Desenvolvimento Humano no Brasil*), which is based on Brazilian Census.

In order to investigate the effects of the reform on student's test scores, data from *Prova Brasil* was used. *Prova Brasil* is a survey carried out by the Ministry of Education containing information on Math and Portuguese test scores for 4<sup>th</sup> and 8<sup>th</sup> grade students. There is also a detailed set of information on students, teachers, and principals for public and private schools. The data consist of a representative sample of schools and are available from 2007 to 2011 (every two years).<sup>43</sup> A municipal panel data was then construed. In the estimates, data on math test scores for students at the 8<sup>th</sup> (9<sup>th</sup>) grade were used. As the data from Census is only available for 2000 and 2010, we use the 2010 census information on

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<sup>42</sup> The drawback of this data is that there is not enough pre reform municipal information available.

<sup>43</sup> Prior to 2007, students' test scores were measured by *Sistema Nacional de Avaliação Básica* (SAEB). However, SAEB data are not representative at the municipal level, but only at the State level.

several municipal characteristics. Compared to 2010, one can consider that 2009 and 2011 municipals' features are quite constant. We also assume that they would not have changed much from 2007 to 2010.

Table 3.4 presents some descriptive statistics for the Prova Brasil data. Students from the North and Northeast regions have the lowest average test scores. These regions also present the lowest share of white students. The proportion of students who have repeated a grade before is extremely high in all regions. In the poorest regions (North and Northeast), more than 40% of the students have repeated a grade before. The data also shows mothers' low level of education. Municipals variables show the great inequalities among regions. The North and Northeast regions present the highest levels of illiteracy rate and lower share of people with a college degree. Besides, around 70% of the children in these regions are considered vulnerable to poverty. The high proportion of children from a poor background certainly represents a great challenge in terms of improvement of student's attainment.

A sample data from the PNAD (Pesquisa Nacional por Amostra de Domicílios) was employed to analyse the effects on education attainment. PNAD is a sample survey which collects annual information on demographic and socioeconomic characteristic of the population such as: education, work, earnings, migration status, fertility and family composition. We use the data from 1992 to 2011 (except 1994, 2000 and 2010 when there was no survey) and focus on individuals who were most affected by the reform – individuals aged 6 to 19.<sup>44</sup> As PNAD is not representative at the municipal level, FUNDEF impact is evaluated at the State level. The sample is restricted to individuals who were born and have always lived in the same State.

Summary statistics for this sample are presented in Table 3.5. According to the Table 3.5 around 84% of the individuals between 6 to 14 attend primary education. The completed years of education is low given the low age of the sample. The proportion of people attending secondary education is remarkably low, around 35% (people aged 15 to 18). Consequently, the share of individuals with complete secondary education is also low (22%). The variable

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<sup>44</sup> The school age in Brazil is from 6 to 17 years old, 18 and 19 years old were also included since there is a high proportion of people with 18 years still attending secondary education.

revenue per capita is the sum of the revenues received from the fund by the municipalities plus the revenue received by the States.<sup>45</sup>

### **3.7 Results**

This section is divided into three subsections. The first one analyses the effects of the reform on schools inputs. The second section investigates the effects of the funding reform on students test scores and the third one focuses on the program impacts on intermediate effects.

#### **3.7.1 School Inputs**

In this section we begin by presenting the effects of the reform on school inputs. Table 3.6a to 3.6c present the estimates of the first-stage regressions. The estimates for the North and Northeast regions were aggregated since they are very similar in many economic and social aspects. Despite the South and Southeast being the richest regions in the country, the Southeast region is much more heterogeneous in terms of income per capita than the South, so the effect on these regions will be analysed separately.

Columns (1), (3), (5) and (7) in Table 3.6a show that simulated municipal per capita revenue is positively correlated with observed municipal per capita revenue. Column (3) indicates that a R\$1 increase in simulated per capita revenue increases actual per capita revenue by R\$0.75. The fact that the coefficients are not equal to 1.0 is justified by the way in which the instrument was built, which considered only the variation on municipal revenues' and maintained constant the level of primary enrolment. In all specifications, the F-statistic on the excluded instrument is over 61.0, suggesting that there are no weak instruments problems.<sup>46</sup> Table 3.6b also presents IV first stage results for simulated per capita revenue interacted with income percentile as instruments. The F-statistics also suggest that the instruments built did not suffer from weak instruments problems. Table 3.6c, in turns, shows the IV first stage results for the variable "Intensity Fundef". This variable was instrumented using the "simulated intensity Fundef" which is based on the simulated revenue. Again, the instrument suggested seems to be quite satisfactory.

Table 3.7a presents OLS and IV estimates of the effects of FUNDEF revenue on educational spending per capita. The estimates for the South and Southeast regions indicate

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<sup>45</sup> There is no information available for the type of regime (cycle/grades) adopted by schools in the 1998 School Census.

<sup>46</sup> All F-statistics computed were above the critical values of Stock and Yogo's (2005) weak ID test.

that an R\$1 increase in revenue per capita results in an R\$0.17 and R\$0.22 increase in education spending per capita (i.e per population, not per student).<sup>47</sup> For the Center-West a R\$1 increase on revenue increases spending per capita by R\$0.23. For the North and Northeast regions an extra Real (R\$) of revenue per capita is associate with an R\$0.27 increase in municipal educational spending. So an extra increase of revenue per capita results in a higher increase in per capita education spending in the poorest regions. For the South and Centre-West, the OLS estimate is smaller in magnitude than IV. Kosec (2011) suggest that there are also some channels for downward bias. If mayors have a high discount rate either because they are in their second term and cannot be re-elected, or because they are corrupt this may lead to less investment in publicly-provided goods like education. This could thus generate a downward-biased on OLS estimates.

It is also important to estimate the effects of a rise in FUNDEF's revenue given by the Federal government on educational spending. Table 3.7b estimates the effects of minimum spending level on educational spending per capita. As discussed before the Federal Government complements funds in cases where the minimum spending levels were not achieved. Only municipalities, which had not achieved the minimum spending per pupil, were entitled to the Federal government grant. During the period analysed an average of 35% of the municipalities received an extra revenue from the Federal Government. Table 3.6b presents the results for each region separately. The results suggest that an increase in the resources intended to complete the minimum spending level increases educational expenditures per capita in all regions. The effect is higher for the North region where a R\$1 increase in minimum spending transfer per pupil increases education spending per capita by R\$0.25. Despite of being, along with the North, one of the regions which have the highest proportion

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<sup>47</sup>We use education spending per capita since from 1998 to 2004 the variable municipal education expenditure is available only in aggregate terms. This variable includes expenditures on all education levels such as childhood education, primary education, secondary education, vocational education, youth and adult education, special needs education, higher education and other education expenditures. For instance, in 2005, expenditures on high education and other education expenditures accounted for almost 10%, on average, of the total education spending. Some municipalities however report spending a much higher share, like 30%, 40%, 50% of their total education expenditure, on higher education and other education expenditures. The School Census data however does not compute the number of students on higher education in the municipalities and the spending reported on "other education expenditures" could be anything related to education. So spending per pupil based on School Census' enrollment levels could actually overestimate the real spending per pupil for some municipalities and thus bias the estimates. It should be noted however that this should not affect much the graphs on spending per pupil. Since spending per pupil were aggregated by region and around 90% to 92%, on average, of municipal education expenditures are not higher education expenditures nor "other education expenditures". Moreover, expenditures on primary education are around 80%, on average, of the total municipal education expenditures.

of municipalities that benefit from Federal transfers, a R1,00 increase in minimum spending transfer per pupil in the Northeast region represents an increase of only R\$0.05. It should be noted however, that Federal transfers represent only a small proportion of the revenues received from FUNDEF. An instrumental variable for the minimum spending level transfers where not constructed since the minimum value per pupil is computed based on total amount collected by the fund in a given year, so it is not based on an exogenous rule.

Table 3.8a and 3.8c show OLS and IV results for school inputs for Centre-West region. The results indicate a decrease in the infrastructure I quality index (basic infrastructure). This is quite an unexpected result. Colum (1) panel B, shows that a R\$1000 increase of revenue per capita is associated with a 0.54 standard deviation decrease in the infrastructure I quality index. This negative effect though is smaller for poorer municipalities. It appears that students were accommodated in schools with somewhat lower-quality basic infrastructure, for example on new schools in areas with worse basic infrastructure. The estimates show a positive effect on infrastructure II quality index for the municipalities most effect by the reform. A R\$1000 increase in revenue per capita is associated with a 0.40 standard deviation increase on infrastructure II quality index. The effects were greater for municipalities with a higher income per capita. The different results on the infrastructure quality indices however seem a bit controversial. Nonetheless it might reflect that a large number of schools in the Center-West region already have accessed to some basic infrastructure. Given that, the additional revenue has a greater effect on the infrastructure quality II index. The additional revenue may have led to the building of new schools on areas with worse basic infrastructure however; on average, the effect on the infrastructure quality II index was larger.

For the variables proportion of teachers with a degree and pupil teacher ratio, the effects of the policy for the lower and upper primary are analysed separately since the results may differ between these two educational levels. In terms of the proportion of teacher with a degree (Table 3.8b), the estimates show a decrease for the municipalities most affected by the reform. This could actually be related to an increase in the influx of new teachers on the lower primary education with secondary education only. The effect seems to be quite the same between poor and wealthy areas. The estimates show however a positive effect of the funding on the proportion of teachers with a degree on the upper primary education for municipalities in the bottom quintiles of income per capita, reinforcing the importance to analyse the two



education levels separately. For the poorest municipalities an increase on R\$1000 in the revenue per capita is associated with a 6 percentage point increase in the proportion of teachers with a degree, which is almost 10% increase over the mean (mean 0.59).

Table 3.8c shows the results for pupil teacher ratio for lower and upper primary education. Column (1) shows a decrease in the pupil teacher ratio in the lower primary. A R\$1000 increase in revenue per capita reduces the pupil teacher ratio in the lower primary by 2.07 on average, which represents a 10% decrease over the mean. However, the estimates show an increase in the pupil teacher ratio for the municipalities with a lower income per capita. The estimates show no effects for the upper primary education. As some studies point out for an increase in the enrolment rates this might suggest that the influx of new students in lower primary in low income municipalities was not offset by an influx of new teachers. Or the reason why we observe an increase in the pupil teacher ratio is that teachers capture the rent - the 60% of the budget being spent on teachers lead to an increase in the wages of teachers rather than an increase in the number of teachers.

Table 3.9a and 3.9c present the OLS and IV results for the South region. Column (2) on Table 3.9a shows a positive effect on the basic infrastructure quality index for low income municipalities. It shows that a R\$1000 increase in revenue per capita is associated with an increase 0.33 standard deviation in infrastructure I quality index for municipalities in the lowest percentile of income per capita. Overall, in terms of the infrastructure II quality index (library, sports facilities and computer lab), the estimates show a small but positive effect.

Table 3.9b display the results for proportion of teachers of a degree. Column (2) and (5) shows an increase in the share of teachers with a higher degree in both lower and upper primary mainly for low income areas. Column (2) ((5)) shows that a R\$1000 increase in per capita revenue is associated with an increase of 0.07 (0.05) in the proportion of teacher with a degree in municipalities in the bottom percentile of income per capita, which represents a 16% (7%) increase over the sample mean. The results for the FUNDEF intensity variable however are negative for both estimates. Table 3.9c show the results for pupil teacher ratio. The estimates show an increase in the number of students per teacher in the poorest regions for both lower and upper primary, which again might suggest that mainly for poorer areas the influx of new students, was not compensated with an increase in the number of teachers hired.

The results though show a reduction on the ratio for municipalities which received two times more than contributed to the fund.

Tables 3.10a to 3.10c present the results for the Southeast region. There is a positive effect on the infrastructure quality I index mainly for the municipalities with a lower income per capita. Column (5), in turn, show a negative effect for on the infrastructure quality II mainly for municipalities in the bottom of income per capita, suggesting that in the poorer areas of the Southeast region the additional revenue were mainly intended to improve school's basic infrastructure. Table 3.10b show a positive effect on the proportion of teachers with a degree for the lower primary education. According to column (2) a R\$1000 increase in revenue per capita increases the proportion of teachers with a degree in 14 percentage points in the municipalities in the bottom percentile of income per capita (33% over the mean). The results also show an increase for the poorest municipalities on the proportion of teacher with a degree in the upper primary education. A R\$1000 increase in revenue per capita is associated with a 27% percentage point increase in the proportion of teachers with a degree, which represents an increase of 37% over the mean. Table 3.10c suggest an increase in the number of pupil teacher ratio in the lower primary mainly for the poorest municipalities which is also true for the upper primary. It might suggest that in the poorest regions the main concern was to increase the levels of enrolments with less attention paid on the pupil teacher ratios.

Finally, Tables 3.11a to 3.11c present the OLS and IV estimates for the North and Northeast regions, the poorest regions in the country. Column (1) and (2) reveal some effects on basic infrastructure with a higher impact for low income municipalities. Results in column (3) shows that municipalities which have received funds that are two times higher than their original contribution have an increase of 0.11 standard deviation in infrastructure quality I index. The estimates however show a negative effect on infrastructure II quality index.

The estimate also indicates a negative effect on the proportion of teachers with a higher degree for the lower primary education for municipalities in the bottom percentile of income per capita. As for the Center-West regions this is probably associated with an influx of new teacher with secondary education only. Columns (4) to (6) show a positive effects for the proportion of teachers with a degree in the upper primary education. A R\$1000 increase in the revenue per capita is associated with a 17 percentage point increase in the proportion of teacher with a degree, an increase of almost 40% over the mean. The effect seems to be the

same between poor and rich regions. Columns (1) to (3) in Table 3.11c show an increase in the proportion of pupil teacher ratio in lower primary education. The estimates are greater for the municipalities in the bottom of income per capita. A R\$1000 increase in the revenue per capita is associated with an increase of 4.8 students for teacher in the lower primary for the poorest municipalities, which is quite a great effect. For the upper primary, the estimates show a decrease in the pupil teacher ratio. In column (4) a R\$1000 increase the revenue per capita decreases the pupil teacher ratio by 1.68 on average. For the municipalities in the bottom percentile of income per capita an increase of R\$1000 reduces pupil teacher ratio by 1.77, which represents of reduction of 10% over the mean.

The differences in the estimates between regions show how important a regional analysis is. The South, Southeast and the North and Northeast regions show an improvement on infrastructure Quality I index, meaning an improvement on schools' basic infrastructure with greater effects for low-income municipalities. The Center-West and the North and Northeast regions present a reduction in proportion of teachers with a degree in the lower primary. This probably suggested an influx on new teachers in this education level with only secondary education. The South and Southeast in turn present an increase in the proportion of qualified teacher in lower primary education. All regions present and increase in the proportion of teacher with a degree in upper primary education, with the effects being greater for low income municipalities. The results also show an increase in the pupil teacher ratio in the lower primary education for all the regions. As some studies point out for an increase in the number of enrolments in the primary education but also an increase in the number of teachers hired, clearly the influx of new teacher were not enough to offset the influx of new students. The Center-West and the North and Northeast regions show no effects and a reduction for the pupil teacher ratio in upper primary. For the South and Southeast regions, there was an increase in the pupil teacher ratio mainly in the poorest regions. Overall, the results show a greater effect of the financing reform on the educational inputs for lower income municipalities, which is quite a positive result of the policy suggesting a reduction in the inequality. The big drawback for these municipalities though was the increase in pupil teacher ratio in almost all regions, showing a necessity to raise the number of teachers in public schools. It might be the case however that the reason why we observe an increase in the pupil teacher ratio is that teachers capture the rent - the 60% of the budget being spent on teachers lead to a increase in the wages of teachers rather than an increase in the number of

teachers, which is not exactly a bad result given the lower salaries of public school teacher's in Brazil. Finally the analysis on school inputs indicates a reduction in the inequality between poorer and richer areas.

### 3.7.2 Student's Test Scores

The previous section presented the effects of the reform on school inputs. Following the overall analysis of the educational policies, this section analyses whether the funding increase brought by the reform and the subsequent increase in teacher spending translated into higher students' test scores.<sup>48</sup>

As mentioned before, the impact of the reform over students' test scores is not only contemporaneous but it is also a result of the years of continuing attendance to a public school with better resources. In order to measure the latter effect, the sample is restricted to students that have only attended public primary schools and that were born in the same municipality they currently live in. We have also created a variable which is simply the sum of all revenues received by the municipality during the period to account for the cumulative effect of educational inputs (Cunha et al, 2006). The assumption is that students from schools in municipalities that have received more resources during the period were more exposed and therefore might have been more positively affected by the policy.<sup>49</sup>

Table 3.12 presents estimates for the first-stage regressions. Panels A, B and C show the first stage regressions for revenue per capita, Fundef intensity and total revenue per capita respectively. All F-statistics computed are higher than the critical values for weak instrument (Stock and Yogo's (2005)). The instrument employed here is the same as the one employed in the schools inputs estimates.

Tables 3.13a to 3.13c present the effects of the reform on test scores using three different policy measures. Table 3.13a show the results for standardized test scores using the contemporaneous revenue per capita for each region. For the Southeast and South region, the OLS and IV estimates show no effects. Column (3) and (4) in panel B indicates a negative and a positive effects for the North and Northeast regions respectively; however, the effects are rather small. Table 3.13b presents OLS and IV estimates for the FUNDEF intensity

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<sup>48</sup> According to the program rules, 60% of total FUNDEF revenue has to be spent on teacher's wages.

<sup>49</sup> According to INEP (2011), the cumulative investment per public school student along the length of theoretical studies in 2011 was around R\$21,703 (\$9,650) for the lower primary level and R\$17,605 (\$7,825) for the upper primary (2013 US\$).

variable. Column (1) in panel B shows that high treated municipalities in the Southeast region presented a decrease in their students' test scores of around 0.12 standard deviation. Table 3.13c presents the cumulative effect of the funding reform. The estimates show no effects for the first three regions (Southeast, South and North) and a positive but small effect for the Northeast region. The lack of substantive positive effect and the negative effect found in the Southeast region might be due to an influx of new students with poorer backgrounds. This however could also indicate that despite the incorporation of these students the policy were not able to increase the quality of their education. Thus, the estimates suggest that the increase in expenditure per pupil did not translate into a higher students' mean performance at least in the period analysed. It should be noted however that we have a very limited data on test scores. The improvement on students' test scores could be happening in first years of the reform as shown by Menezes-Filho and Pazello (2007), or at different points of the distribution.

### **3.7.3 Education Attainment**

In this section, we focus on the effect of the reform on education attainment. As PNAD is not representative at the municipal level, FUNDEF impact is now evaluated at the State level. Given that, FUNDEF total revenue per capita is now the sum of the observed municipal revenue per capita plus the State revenue per capita, so the total revenue received from the fund is the sum of revenue received by the municipalities which is destined to its municipal schools plus the revenue received by the State which is destined to the state schools. In order to deal with the possible endogeneity of the observed State revenue per capita, we have also constructed an instrument based on simulated State revenues. Such instrument is based on the number of students enrolled in public schools in 1996. However, during the period analysed, there was a decline in the number of students enrolled in State schools. Since the majority of students from primary education had actually migrated to municipal schools as municipalities became the main responsible for the offer and management of primary education (while the State became responsible for the secondary education). This change can be seen in Figure 3.11, which shows the number of enrolments in all educational levels in State and Municipal schools. After 1997 there was a clear decrease on the number of students enrolled in State schools. There was also a large increase in the number of students enrolled in municipal schools during the period.

Therefore, the simulated revenue per capita based on the 1996 State enrolment rate actually overestimated some of the observed State's revenues. The total revenue received by a State from the fund is the sum of the revenue received by its municipalities plus the revenue received by the State itself. The revenue received by municipalities goes to its municipal schools while the revenue received by the State goes to its state schools. Because the simulated State revenue actually overestimates the observed State revenue, the instrument for the total revenue is now based on the simulated municipal revenue plus the observed State revenue. This instrument is less subject to endogeneity, though, as State enrolment rates are far more difficult to manipulate since States have a great number of schools spread all over their territories. On the other hand, municipalities with a small number of schools have more power to manipulate their enrolment figures. The amount received from the fund by each State also depends on the amount of taxes and revenues. However, not all taxes linked to fund are State taxes, in fact a great share of them are Federal taxes. Moreover the main State taxes linked to the fund (ICMS, IPVA and ITCMD) have their minimum and maximum values set by the Federal government. Municipals revenues also represent the large share of a State's total FUNDEF revenue since the number of students enrolled in municipal educational system is much higher. All these facts together, suggest that our instrument is less subject to endogeneity problems.

Table 3.14 presents estimates for the first-stage regressions. Panels A and B show the first stage regressions for total revenue per capita and total revenue per capita interacted with State GDP per capita. Both F-statistics computed are higher than the critical values for weak instrument (Stock and Yogo's (2005)).

Table 3.15 presents OLS and IV results for some educational outcomes. Column (1) presents the effects of the reform on the probability to attend secondary education. Despite the large increase in the proportion of children attending primary education, secondary education attendance is still an issue. The IV estimates indicate that a R\$1000 rise in total revenue per pupil increases the probability to attend secondary school by 3 percentage points, which represents a 9% increase over the mean for municipalities in the bottom quintile of income per capita. Given the low attendance in secondary education this does not seem a great increase. Results also indicate a positive effect on the probability to complete primary education (Column 2): a R\$1000 revenue per capita increase leads to a rise of 5 percentage

points in the probability to complete primary education for people aged 14 to 17 years old, which represents almost a 10% rise over the mean for the poorest municipalities.

Column (3) shows the effects on the probability to complete secondary education for people aged 17 to 19.<sup>50</sup> Again, the estimates indicate a greater effect for States with a lower GDP per capita. On average, a R\$ 1000 increase in total revenue per capital is associated with a 4% points rise in the probability to complete secondary education.

Column (4) shows the effects on completed years of schooling for individuals aged 15 to 19 who were affected by the policy. Panel B shows effects only for the lower income States. The estimate indicates that a R\$1000 increase in total revenue increase is associated with a 0.20 years of schooling increase for States in the first percentile of GDP per capita and 0.1 for individual in the second percentile of GDP per capita. In other words, individuals aged 15 to 18 completed 0.20 more years of schooling on the States most affected by the reform.

The estimates thus show some evidence of a positive but a small effect of the reform on educational attainment variables. The effects seem to be concentrated on low income States, in fact the ones most affected by the reform. The inputs analyses also show that the reform had its greatest impact on poorer municipalities. Franco and Menezes-Filho (2010) also found some evidence of positive effect on student's approval rate and a negative effect on the drop-out rates for municipalities most affected by the reform. The lack of a substantive and a generalized effect on education attainment might reflect the absence of a more substantive and widespread effect on schools inputs and the absence of a positive effect on student's test scores. It may also be driven by selection effect whereby post reforms, more poorer students stay in schools, affecting the average attainment.

### **3.8 Conclusions**

Despite the substantial research in the field, the question of whether increasing funding for schools improves student performance remains controversial. Debates about how to improve the quality of public education often focus on whether governments should increase their spending per pupil. As a result, this study aimed at contributing to the literature by evaluating the effects of a large educational funding reform in Brazil.

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<sup>50</sup> We consider that people with 19 years old were also affected because the average age in secondary school for the sample after 1998 was 18.3.

The educational funding reform implemented in Brazil (FUNDEF/B) largely increased education spending across country. One of the aims of the reform was to reduce the disparities in the allocation of resources within and among regions. Besides, by increasing the amount of resources allocated to public schools the reform also aimed at improving the quality of basic education. FUNDEF/EB policy intended at improving the distribution of education funding in order to reduce the large disparities in terms of school inputs and outputs between poor and rich regions. In the period analysed, the poorest regions (North and Northeast) have experienced a significant rise in their spending per pupil. This substantial increase suggests that the reform had, to a large extent, its expected effect.

The empirical work in this chapter has indicated some results that are worth noting. In regards to school inputs, the estimation results suggest a decline in the inequality between poor and rich areas within regions. Overall, the effect of the reform on school inputs seemed to be greater for lower income municipalities, which is quite a desirable result of the policy. This effect could be seen as an important step towards reducing schools' inequalities between poorer and richer areas. The results however indicate an increase in the pupil teacher ratio in almost all regions. This result could indicate that the increase in the number of teachers hired during the period was not enough to offset the influx on new students.

The estimates show no link between educational expenditures and student's test scores. As pointed out by Gordon and Vegas (2005) the reform greatly increase enrolment levels on poorer municipalities. This certainly increased the influx of students with poorer backgrounds on the educational system. However, besides that, the increase in education spending brought by the reform in the period was not able to increase the quality of student's achievement. The results indicate that the increase in expenditure per pupil did not translate into a higher students' performance in terms of standardized test score, at least in the period analysed.

The results show some evidence of a small but positive effect on educational attainment. The effects seem to be concentrated on low income States, in fact the ones most affected by the reform. The estimates show some effect on the proportion of students attending secondary education and an increase on the probability to complete primary and secondary education in the most affected States.



FUNDEF/EB was certainly the major educational policy ever implemented in Brazil and which substantially increased funding to public schools. However, given the amount of resources destined to this policy in the last 16 years the effects on the Brazilian public education seems quite modest.

Table 3.1: Average Years of Schooling for the Adult Population, 1960-2010

|                | 1960 | 1990 | 2000 | 2010 | Ratio<br>2010/1990 | Ratio<br>2010/1960 |
|----------------|------|------|------|------|--------------------|--------------------|
| Argentina      | 5.3  | 7.9  | 8.6  | 9.3  | 1.2                | 1.7                |
| <b>Brazil</b>  | 1.8  | 3.8  | 5.6  | 7.2  | 1.9                | 4.0                |
| Chile          | 5.0  | 8.1  | 8.8  | 9.7  | 1.2                | 1.9                |
| Colombia       | 2.8  | 5.5  | 6.5  | 7.3  | 1.3                | 2.6                |
| Mexico         | 2.6  | 5.5  | 7.4  | 8.5  | 1.5                | 3.3                |
| Peru           | 3.2  | 6.6  | 7.7  | 8.7  | 1.3                | 2.7                |
| Canada         | 8.1  | 10.3 | 11.1 | 11.5 | 1.1                | 1.4                |
| France         | 4.1  | 7.1  | 9.3  | 10.4 | 1.5                | 2.5                |
| United Kingdom | 6.0  | 7.9  | 8.5  | 9.3  | 1.2                | 1.5                |
| USA            | 8.9  | 12.3 | 13.0 | 12.4 | 1.0                | 1.4                |
| China          | 1.4  | 4.9  | 6.6  | 7.5  | 1.6                | 5.2                |
| Japan          | 7.2  | 9.9  | 10.7 | 11.5 | 1.2                | 1.6                |
| Korea, Rep.    | 3.2  | 8.9  | 10.6 | 11.6 | 1.3                | 3.6                |
| OECD average   | 6.1  | 8.9  | 9.9  | 10.7 | 1.2                | 1.7                |

Source: World Bank (2010)

Table 3.2: Descriptive Statistics - School Census

| Variable                                     | 1997            | 2010            |
|--|-----------------|-----------------|
| Computer lab                                 | 0.01<br>(0.06)  | 0.38<br>(0.35)  |
| Sport facilities                             | 0.11<br>(0.23)  | 0.31<br>(0.34)  |
| Science lab                                  | 0.02<br>(0.11)  | 0.05<br>(0.13)  |
| Library                                      | 0.13<br>(0.24)  | 0.35<br>(0.34)  |
| Running water                                | 0.28<br>(0.33)  | 0.59<br>(0.33)  |
| Electricity                                  | 0.61<br>(0.37)  | 0.95<br>(0.15)  |
| Sewage                                       | 0.14<br>(0.28)  | 0.27<br>(0.34)  |
| Principal's office                           | 0.21<br>(0.29)  | 0.65<br>(0.32)  |
| Toilet inside the building                   | 0.63<br>(0.36)  | 0.89<br>(0.21)  |
| Proportion of teachers with a college degree | 0.13<br>(0.19)  | 0.62<br>(0.29)  |
| Pupil teacher ratio                          | 21.22<br>(7.25) | 17.90<br>(4.98) |

Source: School Census. Standard deviation in parentheses.

Table 3.3: Summary Statistics - School Census

| Variables  | Southeast      | South          | North and Northeast | Centre-West    |
|--|----------------|----------------|---------------------|----------------|
| Fraction of municipal schools with a running water                 | 0.59<br>(0.35) | 0.59<br>(0.36) | 0.33<br>(0.28)      | 0.57<br>(0.35) |
| Fraction of municipal schools with electricity                     | 0.92<br>(0.18) | 0.98<br>(0.07) | 0.70<br>(0.32)      | 0.85<br>(0.27) |
| Fraction of municipal schools with sewage                          | 0.53<br>(0.38) | 0.17<br>(0.27) | 0.07<br>(0.14)      | 0.09<br>(0.20) |
| Fraction of municipal schools with principal's office              | 0.51<br>(0.38) | 0.50<br>(0.38) | 0.28<br>(0.28)      | 0.52<br>(0.37) |
| Fraction of municipal schools with toilet inside the building      | 0.90<br>(0.22) | 0.93<br>(0.15) | 0.67<br>(0.33)      | 0.80<br>(0.28) |
| School infrastructure I quality index, first PC from 2-factor PCA  | 0.0<br>(1.74)  | 0.0<br>(1.43)  | 0.0<br>(1.65)       | 0.0<br>(1.69)  |
| Fraction of municipal schools with a computer lab                  | 0.16<br>(0.29) | 0.22<br>(0.33) | 0.05<br>(0.12)      | 0.17<br>(0.30) |
| Fraction of municipal schools with sport facilities                | 0.31<br>(0.34) | 0.40<br>(0.35) | 0.06<br>(0.11)      | 0.26<br>(0.32) |
| Fraction of municipal schools with a library                       | 0.37<br>(0.36) | 0.49<br>(0.37) | 0.09<br>(0.15)      | 0.25<br>(0.32) |
| Fraction of municipal schools with a science lab                   | 0.05<br>(0.14) | 0.08<br>(0.20) | 0.01<br>(0.02)      | 0.02<br>(0.07) |
| School infrastructure II quality index, first PC from 2-factor PCA | 0.0<br>(1.54)  | 0.0<br>(1.51)  | 0.0<br>(1.44)       | 0.0<br>(1.41)  |
| Fraction of primary teachers with a college degree – lower primary | 0.42<br>(0.33) | 0.43<br>(0.32) | 0.17<br>(0.25)      | 0.39<br>(0.34) |
| Fraction of primary teachers with a college degree – upper primary | 0.72<br>(0.31) | 0.71<br>(0.28) | 0.43<br>(0.35)      | 0.59<br>(0.34) |

Notes: Standard deviation in parentheses. Data are aggregated over the 1997 to 2010 period and over municipalities for which data is available (N=66,528). Source: School Census, STN, and IPEADATA

Table 3.3 (continued): Summary Statistics - School Census

| Variables                                       | Southeast            | South                | North and Northeast  | Centre-West          |
|---|----------------------|----------------------|----------------------|----------------------|
| Primary pupil teacher ratio – lower primary     | 18.4<br>(11.4)       | 15.2<br>(7.1)        | 24.5<br>(9.31)       | 20.65<br>(10.05)     |
| Primary pupil teacher ratio – upper primary     | 14.6<br>(10.6)       | 10.1<br>(6.9)        | 16.7<br>(13.3)       | 14.70<br>(10.61)     |
| Revenue per capita (100s, 2011 Reais)           | 7.23<br>(9.33)       | 7.02<br>(12.9)       | 8.07<br>(11.16)      | 6.62<br>(7.34)       |
| Simulated revenue per capita (100s, 2011 Reais) | 4.67<br>(5.49)       | 6.67<br>(8.314)      | 6.78<br>(7.13)       | 5.60<br>(6.45)       |
| Education spending per capita (2011 Reais)      | 321.38<br>(329.07)   | 354.11<br>(883.94)   | 306.03<br>(834.36)   | 312.00<br>(262.19)   |
| Intensity Fundef                                | 0.098<br>(0.69)      | -0.065<br>(0.61)     | 1.01<br>(1.14)       | -0.015<br>(0.77)     |
| Average income per capita (2011 Reais)          | 5902.21<br>(7258.63) | 6663.35<br>(6215.18) | 2408.64<br>(3550.82) | 6054.02<br>(5655.28) |
| Population                                      | 37,455<br>(262,895)  | 22,818<br>(78,365)   | 28,303<br>(107,826)  | 22,220<br>(76,052)   |
| Population aged 7 to 15                         | 6,039<br>(38,578)    | 3,749<br>(11,888)    | 5,631<br>(18,786)    | 3,945<br>(12,446)    |

Notes: Standard deviation in parentheses. Data are aggregated over the 1997 to 2010 period and over municipalities for which data is available (N=66,528). Source: School Census, STN, and IPEADATA

Table 3.4: Descriptive statistics: Prova Brasil and Census 2010 - 8<sup>th</sup> grade

| Variables  | Southeast         | South             | North             | Northeast         | Centre-West       |
|--|-------------------|-------------------|-------------------|-------------------|-------------------|
| Math test score  | 251.60<br>(47.07) | 255.95<br>(43.85) | 231.09<br>(40.63) | 226.15<br>(41.95) | 247.64<br>(43.48) |
| Boy  | 0.47<br>(0.49)    | 0.47<br>(0.50)    | 0.44<br>(0.50)    | 0.43<br>(0.49)    | 0.46<br>(0.50)    |
| White  | 0.36<br>(0.48)    | 0.64<br>(0.48)    | 0.17<br>(0.38)    | 0.20<br>(0.40)    | 0.28<br>(0.45)    |
| Age  | 15.0<br>(0.98)    | 14.85<br>(0.96)   | 15.56<br>(1.53)   | 15.52<br>(1.55)   | 15.05<br>(1.33)   |
| Failure before   | 0.28<br>(0.45)    | 0.31<br>(0.46)    | 0.43<br>(0.50)    | 0.45<br>(0.50)    | 0.34<br>(0.47)    |
| Mother education - higher degree   | 0.11<br>(0.31)    | 0.10<br>(0.29)    | 0.10<br>(0.31)    | 0.11<br>(0.31)    | 0.11<br>(0.32)    |
| Computer   | 0.59<br>(0.49)    | 0.60<br>(0.49)    | 0.23<br>(0.42)    | 0.14<br>(0.35)    | 0.43<br>(0.49)    |
| Work   | 0.17<br>(0.38)    | 0.21<br>(0.41)    | 0.22<br>(0.41)    | 0.23<br>(0.42)    | 0.24<br>(0.43)    |
| Drop-out before : No   | 0.96<br>(0.21)    | 0.97<br>(0.17)    | 0.89<br>(0.31)    | 0.91<br>(0.29)    | 0.91/<br>(0.28)   |
| School age entry:<br>Pre-school  | 0.43<br>(0.49)    | 0.30<br>(0.46)    | 0.35<br>(0.48)    | 0.39<br>(0.49)    | 0.26<br>(0.44)    |
| Schools with cycle regime  | 0.66<br>(0.47)    | 0.11<br>(0.31)    | 0.13<br>(0.33)    | 0.16<br>(0.36)    | 0.22<br>(0.41)    |
| Number of cars   | 0.59<br>(0.72)    | 0.81<br>(0.74)    | 0.19<br>(0.48)    | 0.18<br>(0.45)    | 0.53<br>(0.66)    |
| Number of bedrooms   | 2.36<br>(0.83)    | 2.79<br>(0.75)    | 2.42<br>(0.93)    | 2.52<br>(0.84)    | 2.58<br>(0.78)    |
| Number of bathrooms  | 1.35<br>(0.64)    | 1.34<br>(0.64)    | 1.02<br>(0.71)    | 1.00<br>(0.59)    | 1.30<br>(0.62)    |
| Child mortality rate   | 13.60<br>(1.78)   | 11.29<br>(1.61)   | 20.31<br>(4.24)   | 25.07<br>(6.26)   | 15.43<br>(2.36)   |
| Illiteracy rate  | 5.08<br>(3.46)    | 4.12<br>(2.49)    | 12.46<br>(6.82)   | 23.50<br>(8.65)   | 7.33<br>(3.80)    |
| Share of people with a degree - 25 over  | 14.49<br>(6.76)   | 11.47<br>(6.43)   | 5.55<br>(3.83)    | 4.59<br>(3.75)    | 11.44<br>(5.63)   |
| Share of children vulnerable to poverty  | 33.59<br>(11.42)  | 26.54<br>(13.67)  | 66.82<br>(15.24)  | 76.76<br>(12.18)  | 37.05<br>(12.70)  |
| Unemployment rate  | 7.19<br>(1.79)    | 4.19<br>(1.87)    | 8.43<br>(2.96)    | 8.76<br>(3.61)    | 5.64<br>(1.37)    |
| Share of the population living in a household with a toilet and running water                  | 96.43<br>(4.15)   | 96.83<br>(3.04)   | 58.41<br>(21.54)  | 66.81<br>(19.81)  | 93.33<br>(6.68)   |
| Share of the population living with electricity  | 99.81<br>(0.69)   | 99.78<br>(0.34)   | 92.06<br>(8.85)   | 96.86<br>(4.80)   | 98.79<br>(3.69)   |
| Share of the population living with inadequate water supply and sanitation                     | 0.96<br>(1.90)    | 0.73<br>(1.36)    | 28.13<br>(17.73)  | 15.84<br>(12.51)  | 3.71<br>(4.73)    |
| Share of householders mothers without primary education and at least one child younger than 15 | 14.0<br>(4.43)    | 15.07<br>(5.40)   | 26.17<br>(8.67)   | 25.66<br>(8.93)   | 16.24<br>(7.31)   |
| Revenue per capita (100s, 2011 Reais)  | 18.13<br>(8.32)   | 17.52<br>(8.29)   | 16.56<br>(7.35)   | 18.11<br>(6.41)   | 15.80<br>(5.76)   |
| Total revenue (1000s, R\$2011)   | 9.90<br>(5.25)    | 9.00<br>(5.10)    | 7.74<br>(3.74)    | 8.84<br>(4.10)    | 8.46<br>(3.72)    |

Source: Prova Brasil and Atlas do Desenvolvimento Humano do Brasil. Standard deviation in parentheses.

Table 3.5: Summary Statistics – PNAD (1992-2011)

| Variables   |                      |
|---|----------------------|
| Attending primary education                                     | 0.844<br>(0.338)     |
| Years of schooling  | 3.906<br>(3.095)     |
| Attending secondary education                                   | 0.351<br>(0.430)     |
| Primary education – complete                                    | 0.470<br>(0.498)     |
| Secondary education – complete                                  | 0.215<br>(0.420)     |
| Boy   | 0.507<br>(0.499)     |
| White   | 0.475<br>(0.499)     |
| Age   | 12.985<br>(4.254)    |
| Work  | 0.211<br>(0.408)     |
| Lives with mother   | 0.847<br>(0.360)     |
| Mother education – less than primary education                  | 0.782<br>(0.413)     |
| Mother education – less than high school                        | 0.134<br>(0.341)     |
| Mother education – high school less than college                | 0.079<br>(0.269)     |
| Mother education – college                                      | 0.006<br>(0.073)     |
| Attending 9 years primary education                             | 0.074<br>(0.261)     |
| Household income per capita (R\$ 2011)                          | 582.190<br>(961.47)  |
| Share of public schools with cycle regime                       | 0.194<br>(0.301)     |
| Share of poor   | 0.202<br>(0.118)     |
| Share of people attending a private school                      | 0.162<br>(0.053)     |
| State GDP per capita  | 6345.82<br>(2945.93) |
| Population 6 to 18  | 313,201<br>(264,025) |
| Revenue per capita (States + Municipalities) (100s, 2011 Reais) | 9.47<br>(4.98)       |

Source: PNAD (1992-2011). Standard deviation in parentheses

Table 3.6a: IV First Stage Results - Schools Inputs

| Dependent Variable                                    | Per capita revenue  |                     |                      |                      |                      |                      |                     |                     |
|---|---------------------|---------------------|----------------------|----------------------|----------------------|----------------------|---------------------|---------------------|
|   | Southeast           |                     | South                |                      | North & Northeast    |                      | Centre-West         |                     |
|   | (1)                 | (2)                 | (3)                  | (4)                  | (5)                  | (6)                  | (7)                 | (8)                 |
| Simulated revenue                                     | 0.261***<br>(0.054) | 0.258***<br>(0.056) | 0.750***<br>(0.043)  | 0.773***<br>(0.043)  | 0.450***<br>(0.021)  | 0.364***<br>(0.026)  | 0.500***<br>(0.046) | 0.477***<br>(0.063) |
| Simulated revenue*Income per capita – 1 <sup>st</sup> |                     | -0.047<br>(0.079)   |                      | -0.209***<br>(0.023) |                      | 0.135***<br>(0.017)  |                     | 0.011<br>(0.074)    |
| Simulated revenue*Income per capita – 2 <sup>nd</sup> |                     | -0.048<br>(0.066)   |                      | -0.162***<br>(0.022) |                      | 0.092***<br>(0.016)  |                     | -0.020<br>(0.056)   |
| Simulated revenue*Income per capita – 3 <sup>th</sup> |                     | 0.090<br>(0.064)    |                      | -0.125***<br>(0.019) |                      | 0.074***<br>(0.015)  |                     | 0.063<br>(0.049)    |
| Income per capita - First percentile                  | -41.70<br>(36.18)   | -28.28<br>(51.23)   | -45.01***<br>(13.00) | 45.43***<br>(17.16)  | -25.73*<br>(13.76)   | -89.57***<br>(14.95) | -36.55<br>(29.37)   | -44.34<br>(29.24)   |
| Income per capita - Second percentile                 | -75.40**<br>(34.62) | -59.99<br>(43.70)   | -20.30*<br>(10.91)   | 46.04***<br>(16.52)  | -2.94<br>(12.67)     | -45.13***<br>(14.00) | 18.83<br>(22.04)    | 26.45<br>(27.30)    |
| Income per capita - Third percentile                  | -9.08<br>(24.71)    | -36.15<br>(23.05)   | -11.66<br>(7.83)     | 42.42***<br>(12.13)  | 1.67<br>(11.13)      | -33.54***<br>(12.14) | 21.48<br>(17.76)    | -6.16<br>(21.36)    |
| Population  | 0.039<br>(0.025)    | 0.037*<br>(0.022)   | 0.026<br>(0.039)     | 0.058<br>(0.037)     | 0.035<br>(0.040)     | 0.040<br>(0.043)     | -0.167*<br>(0.094)  | -0.162*<br>(0.092)  |
| 7-15 population                                       | 0.074<br>(0.063)    | 0.071<br>(0.061)    | -0.271**<br>(0.114)  | -0.331***<br>(0.107) | -0.242***<br>(0.104) | -0.267***<br>(0.131) | -0.445*<br>(0.244)  | -0.429*<br>(0.240)  |
| Other municipal revenues                              | 1.428<br>(0.979)    | 1.429<br>(0.982)    | -0.002<br>(0.003)    | -0.003<br>(0.003)    | 0.055<br>(0.042)     | 0.070<br>(0.046)     | 0.020<br>(0.070)    | -0.005<br>(0.067)   |
| N   | 15,706              |                     | 13,818               | 13,818               | 20,253               | 20,253               | 4,957               | 4,957               |
| Municipalities  | 1348                | 1348                | 1114                 | 1114                 | 1891                 | 1891                 | 398                 | 398                 |
| F stat, Excluded Instruments                          | 215.33              | 65.22               | 327.25               | 94.25                | 365.9                | 101.0                | 78.90               | 61.35               |

Notes: Robust standard errors in parentheses and clustered at the municipality-year level. All specifications include municipality and year fixed effects, municipality specific effects, as well as a linear time trend interacted with 1996 primary enrolment and primary enrolment squared. \*\*\* indicates  $p < 0.01$ , \*\* indicates  $p < 0.05$ , \* indicates  $p < 0.1$ .



Table 3.6b: IV First Stage Results - Schools Inputs

| Dependent Variable                                    | Per capita revenue*income per capita |                         |                         |                         |
|---|--------------------------------------|-------------------------|-------------------------|-------------------------|
|   | Southeast                            | South                   | North&Northeast         | Centre-West             |
|   | (1)                                  | (2)                     | (3)                     | (4)                     |
| Simulated revenue                                     | 1.276***<br>(0.207)                  | 3.168***<br>(0.176)     | 1.985***<br>(0.104)     | 2.434***<br>(0.253)     |
| Simulated revenue*Income per capita – 1 <sup>st</sup> | -2.515***<br>(0.252)                 | -2.927***<br>(0.085)    | -2.265***<br>(0.066)    | -2.628***<br>(0.235)    |
| Simulated revenue*Income per capita - 2 <sup>nd</sup> | -1.602***<br>(0.217)                 | -2.133***<br>(0.086)    | -1.444***<br>(0.065)    | -1.777***<br>(0.220)    |
| Simulated revenue*Income per capita - 3 <sup>th</sup> | -0.485**<br>(0.214)                  | -1.256***<br>(0.076)    | -0.626***<br>(0.062)    | -0.733***<br>(0.203)    |
| Income per capita - First percentile                  | -821.504***<br>(169.436)             | -187.358***<br>(60.592) | -665.779***<br>(54.649) | -345.146***<br>(99.878) |
| Income per capita - Second percentile                 | -742.990***<br>(146.030)             | -28.746<br>(58.415)     | -432.641***<br>(52.168) | -152.480<br>(95.082)    |
| Income per capita - Third percentile                  | -444.722***<br>(81.311)              | 47.302<br>(48.983)      | -228.499***<br>(46.719) | -113.083<br>(79.748)    |
| Population  | 0.136*<br>(0.076)                    | 0.156<br>(0.162)        | -0.272<br>(0.343)       | -0.338<br>(0.340)       |
| 7-15 population                                       | 0.330*<br>(0.194)                    | -0.421<br>(0.462)       | -0.278**<br>(0.128)     | -1.372<br>(0.953)       |
| Other municipal revenue                               | 4.306<br>(3.187)                     | -0.010<br>(0.012)       | 0.305*<br>(0.177)       | 0.140<br>(0.277)        |
| N   | 15,706                               | 13,818                  | 20,253                  | 4,957                   |
| Municipalities  | 1348                                 | 1114                    | 1891                    | 398                     |
| F stat, Excluded Instruments                          | 205.13                               | 222.55                  | 235.33                  | 236.19                  |

Notes: Robust standard errors in parentheses and clustered at the municipality-year level. All specifications include municipality and year fixed effects, municipality specific effects as well as a linear time trend interacted with 1996 primary enrolment and primary enrolment squared. \*\*\* indicates  $p < 0.01$ , \*\* indicates  $p < 0.05$ , \* indicates  $p < 0.1$ .

Table 3.6c: IV First Stage Results - Schools Inputs

| Dependent Variable                    | Intensity Fundef    |                     |                     |                     |
|---------------------------------------|---------------------|---------------------|---------------------|---------------------|
|                                       | Southeast           | South               | North&Northeast     | Centre-West         |
|                                       | (1)                 | (2)                 | (3)                 | (4)                 |
| Simulated Intensity Fundef            | 0.521***<br>(0.047) | 0.551***<br>(0.114) | 0.555***<br>(0.031) | 0.927***<br>(0.032) |
| Income per capita - First percentile  | 0.024<br>(0.077)    | -0.072*<br>(0.041)  | -0.059<br>(0.047)   | -0.135**<br>(0.066) |
| Income per capita - Second percentile | 0.065<br>(0.080)    | -0.014<br>(0.042)   | -0.017<br>(0.042)   | 0.036<br>(0.053)    |
| Income per capita - Third percentile  | -0.034<br>(0.031)   | -0.012<br>(0.026)   | -0.024<br>(0.037)   | 0.080**<br>(0.040)  |
| Population                            | 0.000<br>(0.000)    | 0.000<br>(0.000)    | 0.000**<br>(0.000)  | 0.001***<br>(0.000) |
| 7-15 population                       | 0.000<br>(0.000)    | 0.000<br>(0.000)    | -0.000*<br>(0.000)  | -0.001<br>(0.001)   |
| Other municipal revenue               | 0.000**<br>(0.000)  | -0.000<br>(0.000)   | 0.000**<br>(0.000)  | -0.000<br>(0.000)   |
| N                                     | 15,175              | 13,423              | 19,649              | 4,752               |
| Municipalities                        | 1348                | 1114                | 1891                | 398                 |
| F stat, Excluded Instruments          | 822                 | 1155                | 1583                | 633.4               |

Notes: Robust standard errors in parentheses and clustered at the municipality-year level. All specifications include municipality and year fixed effects, municipality specific effects as well as a linear time trend interacted with 1996 primary enrolment and primary enrolment squared. \*\*\* indicates  $p < 0.01$ , \*\* indicates  $p < 0.05$ , \* indicates  $p < 0.1$ .

Table 3.7a: OLS and IV Results: Education Spending per capita

| Dependent Variable                                | Education Spending per capita |                     |                             |                      |
|---|-------------------------------|---------------------|-----------------------------|----------------------|
|   | Southeast<br>(1)              | South<br>(2)        | North &<br>Northeast<br>(3) | Centre-West<br>(4)   |
| <b>Panel A: OLS Results</b>                       |                               |                     |                             |                      |
| Revenue   | 0.205***<br>(0.012)           | 0.189***<br>(0.030) | 0.351***<br>(0.043)         | 0.109***<br>(0.014)  |
| Income per capita – 1 <sup>st</sup><br>percentile | -22.399**<br>(11.164)         | -11.555<br>(18.352) | -7.522<br>(10.725)          | -19.188**<br>(7.614) |
| Income per capita – 2 <sup>nd</sup><br>percentile | -16.496<br>(10.928)           | 7.576<br>(8.122)    | -14.544*<br>(7.484)         | -12.197**<br>(5.664) |
| Income per capita – 3 <sup>th</sup><br>percentile | 1.955<br>(4.106)              | 5.414<br>(5.830)    | -3.820<br>(4.992)           | 4.799<br>(3.926)     |
| Population  | 0.002<br>(0.005)              | -0.042<br>(0.035)   | 0.055<br>(0.060)            | -0.095***<br>(0.035) |
| 7-15 population                                   | 0.041**<br>(0.019)            | 0.110<br>(0.094)    | -0.086<br>(0.090)           | -0.004<br>(0.071)    |
| Other municipal revenue                           | 0.127***<br>(0.039)           | 0.013<br>(0.018)    | 0.013<br>(0.055)            | 0.045**<br>(0.023)   |
| R <sup>2</sup>                                    | 0.901                         | 0.769               | 0.666                       | 0.915                |
| <b>Panel B: IV Results</b>                        |                               |                     |                             |                      |
| Simulated Revenue                                 | 0.167***<br>(0.028)           | 0.216***<br>(0.045) | 0.265***<br>(0.100)         | 0.225***<br>(0.060)  |
| Income per capita – 1 <sup>st</sup><br>percentile | -22.604**<br>(9.741)          | -1.348<br>(19.393)  | 0.827<br>(11.036)           | -10.053<br>(8.153)   |
| Income per capita – 2 <sup>nd</sup><br>percentile | -12.399<br>(9.909)            | 6.170<br>(8.496)    | -8.699<br>(6.931)           | -7.570<br>(6.314)    |
| Income per capita – 3 <sup>th</sup><br>percentile | -0.912<br>(3.750)             | 6.314<br>(6.145)    | -2.935<br>(5.251)           | 3.455<br>(4.488)     |
| Population  | 0.008***<br>(0.003)           | -0.087**<br>(0.036) | 0.075<br>(0.082)            | -0.066*<br>(0.040)   |
| 7-15 population                                   | 0.043<br>(0.067)              | 0.221**<br>(0.094)  | -0.043**<br>(0.020)         | 0.042<br>(0.084)     |
| Other municipal revenue                           | 0.213<br>(0.231)              | -0.031<br>(0.056)   | 0.130**<br>(0.056)          | 0.068<br>(0.70)      |
| R <sup>2</sup>                                    | 0.880                         | 0.687               | 0.556                       | 0.873                |
| N   | 15,706                        | 13,818              | 20,253                      | 4,957                |

Notes: Observed revenue is instrumented with simulated revenue. Clustered standard errors at the municipality-year level in parentheses. All specifications include a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .10$ .

Table 3.7b: Minimum expending levels transfers

| Dependent Variable                             | Education Spending per capita |                        |                       |                        |                     |
|--|-------------------------------|------------------------|-----------------------|------------------------|---------------------|
|  | Centre-West                   | North                  | Northeast             | Southeast              | South               |
|  | (1)                           | (2)                    | (3)                   | (4)                    | (5)                 |
| <i>OLS Results</i>                             |                               |                        |                       |                        |                     |
| “Minimum spending level” transfers             | 0.042***<br>(0.009)           | 0.250*<br>(0.145)      | 0.048***<br>(0.011)   | 0.184***<br>(0.020)    | 0.143***<br>(0.049) |
| Income per capita – 1 <sup>st</sup> percentile | -33.416**<br>(14.074)         | -60.122***<br>(18.943) | -25.425***<br>(8.091) | -30.581***<br>(11.092) | -3.488<br>(7.266)   |
| Income per capita – 2 <sup>nd</sup> percentile | -19.215<br>(14.529)           | -15.566<br>(18.513)    | -13.115**<br>(5.724)  | -32.218***<br>(10.576) | 2.119<br>(5.879)    |
| Income per capita – 3 <sup>th</sup> percentile | 6.611<br>(4.387)              | 3.388<br>(7.133)       | -7.918**<br>(3.426)   | -2.419<br>(4.118)      | 3.290<br>(4.122)    |
| Population                                     | -0.098**<br>(0.048)           | -0.055**<br>(0.026)    | 0.010<br>(0.010)      | -0.000<br>(0.005)      | -0.007<br>(0.025)   |
| 7-15 population                                | -0.067<br>(0.067)             | 0.098<br>(0.156)       | -0.104**<br>(0.049)   | 0.044***<br>(0.015)    | 0.048<br>(0.069)    |
| Other municipal revenue                        | 0.009<br>(0.043)              | 0.106<br>(0.347)       | 0.018<br>(0.040)      | 0.167***<br>(0.039)    | -0.002<br>(0.003)   |
| R <sup>2</sup>                                 | 0.868                         | 0.489                  | 0.659                 | 0.887                  | 0.904               |
| N  | 15,175                        | 13,423                 | 19,649                | 4,752                  | 15,175              |

Notes: Clustered standard errors at the municipality-year level in parentheses. All specifications include year and municipality fixed effect as well as municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .10$ .

Table 3.8a: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index - Centre-West

| Dependent Variable                                    | Infrastructure<br>I<br>Quality<br>Index<br>(1) | Infrastructure<br>I<br>Quality<br>Index<br>(2) | Infrastructure<br>I<br>Quality<br>Index<br>(3) | Infrastructure<br>II<br>Quality<br>Index<br>(4) | Infrastructure<br>II<br>Quality<br>Index<br>(5) | Infrastructure<br>II<br>Quality<br>Index<br>(6) |
|---|--|--|--|---|---|---|
| <b>Panel A: OLS Results</b>                           |  |  |  |   |   |   |
| Revenue   | -0.004<br>(0.003)                              | -0.003<br>(0.003)                              |  | 0.008*<br>(0.005)                               | 0.021***<br>(0.005)                             |   |
| Revenue*Income per capita - 1 <sup>st</sup>           |  | -0.010*<br>(0.006)                             |  |   | -0.002<br>(0.007)                               |   |
| Revenue*Income per capita - 2 <sup>sd</sup>           |  | -0.002<br>(0.005)                              |  |   | -0.006<br>(0.006)                               |   |
| Revenue*Income per capita - 3 <sup>th</sup>           |  | 0.000<br>(0.004)                               |  |   | -0.044***<br>(0.010)                            |   |
| Fundef Intensity                                      |  |  | -0.024<br>(0.021)                              |   |   | 0.113***<br>(0.036)                             |
| <b>Panel B: IV Results</b>                            |  |  |  |   |   |   |
| Simulated revenue                                     | -0.054***<br>(0.007)                           | -0.066***<br>(0.008)                           |  | 0.040***<br>(0.011)                             | 0.053***<br>(0.010)                             |   |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |  | 0.054***<br>(0.006)                            |  |   | -0.031***<br>(0.007)                            |   |
| Simulated revenue*Income per capita - 2 <sup>sd</sup> |  | 0.034***<br>(0.006)                            |  |   | 0.002<br>(0.007)                                |   |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |  | 0.003<br>(0.006)                               |  |   | -0.022**<br>(0.011)                             |   |
| Simulated Fundef Intensity                            |  |  | -0.064*<br>(0.036)                             |   |   | 0.084<br>(0.056)                                |
| N   | 4,469  | 4,469  | 4,469  | 4,469   | 4,469   | 4,469   |
| Municipalities  | 398  | 398  | 398  | 398   | 398   | 398   |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$ .

Table 3.8b: OLS and IV Results: Proportion of Teachers with a Degree - Centre-West

| Dependent Variable                                    | Proportion of teachers with a degree - lower primary | Proportion of teachers with a degree – lower primary | Proportion of teachers with a degree – lower primary | Proportion of teachers with a degree – upper primary | Proportion of teachers with a degree – upper primary | Proportion of teachers with a degree – upper primary |
|---|--|--|--|--|--|--|
|   | (1)  | (2)  | (3)  | (4)  | (5)  | (6)  |
| <b>Panel A: OLS Results</b>                           |  |  |  |  |  |  |
| Revenue   | -0.001<br>(0.001)                                    | 0.000<br>(0.001)                                     |  | 0.000<br>(0.001)                                     | -0.000<br>(0.001)                                    |  |
| Revenue*Income per capita - 1 <sup>st</sup>           |  | 0.004**<br>(0.002)                                   |  |  | 0.003*<br>(0.002)                                    |  |
| Revenue*Income per capita - 2 <sup>nd</sup>           |  | -0.002<br>(0.001)                                    |  |  | 0.002<br>(0.001)                                     |  |
| Revenue*Income per capita - 3 <sup>th</sup>           |  | -0.003**<br>(0.002)                                  |  |  | -0.001<br>(0.001)                                    |  |
| Fundef Intensity                                      |  |  | -0.003<br>(0.006)                                    |  |  | -0.000<br>(0.006)                                    |
| <b>Panel B: IV Results</b>                            |  |  |  |  |  |  |
| Simulated revenue                                     | -0.007***<br>(0.002)                                 | -0.005***<br>(0.002)                                 |  | -0.003<br>(0.002)                                    | -0.006***<br>(0.002)                                 |  |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |  | 0.002<br>(0.003)                                     |  |  | 0.012***<br>(0.002)                                  |  |
| Simulated revenue*Income per capita - 2 <sup>sd</sup> |  | 0.000<br>(0.002)                                     |  |  | 0.011***<br>(0.002)                                  |  |
| Simulated revenue*Income per capita – 3 <sup>th</sup> |  | -0.007***<br>(0.002)                                 |  |  | -0.001<br>(0.001)                                    |  |
| Simulated Fundef Intensity                            |  |  | 0.007<br>(0.008)                                     |  |  | 0.009<br>(0.010)                                     |
| N   | 4,469  | 4,469  | 4,469  | 4,469  | 4,469  | 4,469  |
| Municipalities  | 398  | 398  | 398  | 398  | 398  | 398  |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$ .

Table 3.8c: OLS and IV Results: Pupil Teacher Ratio - Centre-West

| Dependent Variable                                    | Pupil teacher ratio – lower primary | Pupil teacher ratio – lower primary | Pupil teacher ratio – lower primary | Pupil teacher ratio – upper primary | Pupil teacher ratio – upper primary | Pupil teacher ratio – upper primary |
|---|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
|   | (1)                                 | (2)                                 | (3)                                 | (4)                                 | (5)                                 | (6)                                 |
| <b>Panel A: OLS Results</b>                           |                                     |                                     |                                     |                                     |                                     |                                     |
| Revenue   | -0.059<br>(0.047)                   | -0.078<br>(0.055)                   |                                     | 0.040<br>(0.060)                    | 0.046<br>(0.060)                    |                                     |
| Revenue*Income per capita - 1 <sup>st</sup>           |                                     | 0.263***<br>(0.066)                 |                                     |                                     | -0.001<br>(0.050)                   |                                     |
| Revenue*Income per capita - 2 <sup>nd</sup>           |                                     | 0.041<br>(0.050)                    |                                     |                                     | 0.019<br>(0.066)                    |                                     |
| Revenue*Income per capita - 3 <sup>th</sup>           |                                     | -0.043<br>(0.068)                   |                                     |                                     | -0.040<br>(0.075)                   |                                     |
| Fundef Intensity                                      |                                     |                                     | -0.053<br>(0.251)                   |                                     |                                     | 0.598*<br>(0.346)                   |
| <b>Panel B: IV Results</b>                            |                                     |                                     |                                     |                                     |                                     |                                     |
| Simulated revenue                                     | -0.207***<br>(0.064)                | -0.337***<br>(0.063)                |                                     | -0.112<br>(0.071)                   | -0.094<br>(0.068)                   |                                     |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |                                     | 0.472***<br>(0.070)                 |                                     |                                     | 0.072<br>(0.079)                    |                                     |
| Simulated revenue*Income per capita - 2 <sup>sd</sup> |                                     | 0.257***<br>(0.058)                 |                                     |                                     | 0.116<br>(0.074)                    |                                     |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |                                     | 0.060<br>(0.071)                    |                                     |                                     | -0.079<br>(0.080)                   |                                     |
| Simulated Fundef Intensity                            |                                     |                                     | -0.019<br>(0.316)                   |                                     |                                     | 0.236<br>(0.411)                    |
| N   | 4,469                               | 4,469                               | 4,469                               | 4,469                               | 4,469                               | 4,469                               |
| Municipalities  | 398                                 | 398                                 | 398                                 | 398                                 | 398                                 | 398                                 |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$

Table 3.9a: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index - South

| Dependent Variable                                    | Infrastructure<br>I<br>Quality Index<br>(1) | Infrastructure<br>I<br>Quality<br>Index<br>(2) | Infrastructure<br>I<br>Quality<br>Index<br>(3) | Infrastructure<br>II<br>Quality<br>Index<br>(4) | Infrastructure<br>II<br>Quality<br>Index<br>(5) | Infrastructure<br>II<br>Quality<br>Index<br>(6) |
|---|---|--|--|---|---|---|
| <b>Panel A: OLS Results</b>                           |   |  |  |   |   |   |
| Revenue   | 0.003**<br>(0.001)                          | 0.004***<br>(0.001)                            |  | 0.004*<br>(0.002)                               | 0.001<br>(0.002)                                |   |
| Revenue*Income per capita - 1 <sup>st</sup>           |   | -0.007<br>(0.005)                              |  |   | 0.027***<br>(0.006)                             |   |
| Revenue*Income per capita - 2 <sup>nd</sup>           |   | -0.006<br>(0.004)                              |  |   | 0.026***<br>(0.006)                             |   |
| Revenue*Income per capita - 3 <sup>th</sup>           |   | -0.003<br>(0.004)                              |  |   | 0.010*<br>(0.006)                               |   |
| Fundef Intensity                                      |   |  | 0.015<br>(0.021)                               |   |   | 0.075*<br>(0.043)                               |
| <b>Panel B: IV Results</b>                            |   |  |  |   |   |   |
| Simulated revenue                                     | -0.002**<br>(0.001)                         | -0.001**<br>(0.001)                            |  | 0.006**<br>(0.003)                              | 0.005**<br>(0.002)                              |   |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |   | 0.034***<br>(0.004)                            |  |   | -0.006<br>(0.007)                               |   |
| Simulated revenue*Income per capita - 2 <sup>nd</sup> |   | 0.015***<br>(0.005)                            |  |   | 0.001<br>(0.007)                                |   |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |   | 0.014***<br>(0.005)                            |  |   | 0.004<br>(0.007)                                |   |
| Simulated Fundef Intensity                            |   |  | -0.038<br>(0.045)                              |   |   | 0.164***<br>(0.052)                             |
| N   | 29,682                                      | 29,682   | 29,682   | 29,682  | 29,682  | 29,682  |
| Municipalities  | 2461  | 2461   | 2461   | 2461  | 2461  | 2461  |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$



Table 3.9b: OLS and IV Results: Proportion of Teachers with a Degree - South

| Dependent Variable                                    | Proportion of teachers with a degree – lower primary | Proportion of teachers with a degree - lower primary | Proportion of teachers with a degree - lower primary | Proportion of teachers with a degree - upper primary | Proportion of teachers with a degree - upper primary | Proportion of teachers with a degree - upper primary |
|---|--|--|--|--|--|--|
|   | (1)  | (2)  | (3)  | (4)  | (5)  | (6)  |
| <b>Panel A: OLS Results</b>                           |  |  |  |  |  |  |
| Revenue   | 0.000<br>(0.000)                                     | -0.000<br>(0.000)                                    |  | 0.001**<br>(0.000)                                   | 0.001***<br>(0.000)                                  |  |
| Revenue*Income per capita - 1 <sup>st</sup>           |  | 0.006***<br>(0.001)                                  |  |  | 0.000<br>(0.002)                                     |  |
| Revenue*Income per capita - 2 <sup>nd</sup>           |  | 0.002**<br>(0.001)                                   |  |  | 0.001<br>(0.001)                                     |  |
| Revenue*Income per capita - 3 <sup>th</sup>           |  | 0.003***<br>(0.001)                                  |  |  | 0.002*<br>(0.001)                                    |  |
| Fundef Intensity                                      |  |  | -0.007<br>(0.004)                                    |  |  | 0.003<br>(0.005)                                     |
| <b>Panel B: IV Results</b>                            |  |  |  |  |  |  |
| Simulated revenue                                     | 0.000<br>(0.002)                                     | 0.000<br>(0.001)                                     |  | 0.001*<br>(0.000)                                    | 0.001<br>(0.001)                                     |  |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |  | 0.007***<br>(0.002)                                  |  |  | 0.005**<br>(0.002)                                   |  |
| Simulated revenue*Income per capita - 2 <sup>nd</sup> |  | 0.005***<br>(0.002)                                  |  |  | 0.007***<br>(0.003)                                  |  |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |  | 0.004***<br>(0.002)                                  |  |  | 0.005***<br>(0.002)                                  |  |
| Simulated Fundef Intensity                            |  |  | -0.042***<br>(0.011)                                 |  |  | -0.060***<br>(0.020)                                 |
| N   | 29,682   | 29,682   | 29,682   | 29,682   | 29,682   | 29,682   |
| Municipalities  | 2461   | 2461   | 2461   | 2461   | 2461   | 2461   |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$

Table 3.9c: OLS and IV Results: Pupil teacher ratio - South

| Dependent Variable                                    | Pupil teacher ratio- lower primary<br>(1) | Pupil teacher ratio- lower primary<br>(2) | Pupil teacher ratio- lower primary<br>(3) | Pupil teacher ratio- upper primary<br>(4) | Pupil teacher ratio- upper primary<br>(5) | Pupil teacher ratio- upper primary<br>(6) |
|---|---|---|---|---|---|---|
| <b>Panel A: OLS Results</b>                           |   |   |   |   |   |   |
| Revenue   | 0.001<br>(0.010)                          | -0.023*<br>(0.012)                        |   | 0.171**<br>(0.067)                        | 0.127***<br>(0.049)                       |   |
| Revenue*Income per capita - 1 <sup>st</sup>           |   | 0.194***<br>(0.037)                       |   |   | 0.646***<br>(0.223)                       |   |
| Revenue*Income per capita - 2 <sup>nd</sup>           |   | 0.165***<br>(0.037)                       |   |   | 0.516***<br>(0.106)                       |   |
| Revenue*Income per capita - 3 <sup>th</sup>           |   | 0.112**<br>(0.035)                        |   |   | 0.392**<br>(0.106)                        |   |
| Fundef Intensity                                      |   |   | -0.085<br>(0.194)                         |   |   | 2.835***<br>(0.711)                       |
| <b>Panel B: IV Results</b>                            |   |   |   |   |   |   |
| Simulated revenue                                     | 0.002<br>(0.015)                          | -0.003<br>(0.007)                         |   | 0.019<br>(0.017)                          | 0.001<br>(0.005)                          |   |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |   | 0.325***<br>(0.047)                       |   |   | -0.001<br>(0.004)                         |   |
| Simulated revenue*Income per capita - 2 <sup>sd</sup> |   | 0.298***<br>(0.041)                       |   |   | 0.274**<br>(0.15)                         |   |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |   | 0.182***<br>(0.042)                       |   |   | 0.167**<br>(0.11)                         |   |
| Simulated Fundef Intensity                            |   |   | -2.165***<br>(0.427)                      |   |   | -1.375**<br>(0.88)                        |
| N   | 29,682                                    | 29,682                                    | 29,682                                    | 29,682                                    | 29,682                                    | 29,682                                    |
| Municipalities  | 2461                                      | 2461                                      | 2461                                      | 2461                                      | 2461                                      | 2461                                      |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$

Table 3.10a: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index – Southeast

| Dependent Variable                                    | Infrastructure<br>I<br>Quality Index<br>(1) | Infrastructure<br>I<br>Quality<br>Index<br>(2) | Infrastructure<br>I<br>Quality<br>Index<br>(3) | Infrastructure<br>II<br>Quality<br>Index<br>(4) | Infrastructure<br>II<br>Quality<br>Index<br>(5) | Infrastructure<br>II<br>Quality<br>Index<br>(6) |
|---|---|--|--|---|---|---|
| <b>Panel A: OLS Results</b>                           |   |  |  |   |   |   |
| Revenue   | 0.004***<br>(0.001)                         | 0.009***<br>(0.003)                            |  | -0.008**<br>(0.004)                             | -0.027***<br>(0.007)                            |   |
| Revenue*Income per capita - 1 <sup>st</sup>           |   | -0.010***<br>(0.003)                           |  |   | 0.028***<br>(0.007)                             |   |
| Revenue*Income per capita - 2 <sup>sd</sup>           |   | -0.003<br>(0.003)                              |  |   | 0.024***<br>(0.007)                             |   |
| Revenue*Income per capita - 3 <sup>th</sup>           |   | -0.005*<br>(0.003)                             |  |   | 0.022***<br>(0.006)                             |   |
| Fundef Intensity                                      |   |  | 0.008<br>(0.013)                               |   |   | -0.069**<br>(0.031)                             |
| <b>Panel B: IV Results</b>                            |   |  |  |   |   |   |
| Simulated revenue                                     | 0.005***<br>(0.002)                         | -0.014***<br>(0.004)                           |  | -0.003<br>(0.005)                               | -0.021***<br>(0.008)                            |   |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |   | 0.088***<br>(0.008)                            |  |   | -0.026***<br>(0.008)                            |   |
| Simulated revenue*Income per capita - 2 <sup>sd</sup> |   | 0.039***<br>(0.004)                            |  |   | 0.021***<br>(0.008)                             |   |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |   | 0.022***<br>(0.003)                            |  |   | 0.027***<br>(0.007)                             |   |
| Simulated Fundef Intensity                            |   |  | -0.065<br>(0.020)                              |   |   | -0.033<br>(0.040)                               |
| N   | 29,682                                      | 29,682   | 29,682   | 29,682  | 29,682  | 29,682  |
| Municipalities  | 2461  | 2461   | 2461   | 2461  | 2461  | 2461  |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$

Table 3.10b: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index – Southeast

| Dependent Variable                                    | Proportion of teachers with a degree - lower primary<br>(1) | Proportion of teachers with a degree - lower primary<br>(2) | Proportion of teachers with a degree - lower primary<br>(3) | Proportion of teachers with a degree - upper primary<br>(4) | Proportion of teachers with a degree - upper primary<br>(5) | Proportion of teachers with a degree - upper primary<br>(6) |
|---|---|---|---|---|---|---|
| <i>Panel A: OLS Results</i>                           |   |   |   |   |   |   |
| Revenue   | -0.000<br>(0.000)   | -0.003***<br>(0.001)  |   | 0.001**<br>(0.000)  | 0.002**<br>(0.001)  |   |
| Revenue*Income per capita - 1 <sup>st</sup>           |   | 0.007***<br>(0.002)   |   |   | 0.001<br>(0.002)  |   |
| Revenue*Income per capita - 2 <sup>nd</sup>           |   | 0.007***<br>(0.001)   |   |   | 0.000<br>(0.001)  |   |
| Revenue*Income per capita - 3 <sup>th</sup>           |   | 0.004***<br>(0.001)   |   |   | -0.001<br>(0.001)   |   |
| Fundef Intensity                                      |   |   | 0.007<br>(0.004)  |   |   | 0.026***<br>(0.003)   |
| <i>Panel B: IV Results</i>                            |   |   |   |   |   |   |
| Simulated revenue                                     | 0.004**<br>(0.002)  | 0.001<br>(0.000)  |   | 0.001*<br>(0.000)   | -0.001<br>(0.002)   |   |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |   | 0.014***<br>(0.004)   |   |   | 0.027***<br>(0.004)   |   |
| Simulated revenue*Income per capita - 2 <sup>nd</sup> |   | 0.006***<br>(0.002)   |   |   | 0.000<br>(0.002)  |   |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |   | 0.004**<br>(0.002)  |   |   | 0.002**<br>(0.001)  |   |
| Simulated Fundef Intensity                            |   |   | 0.019***<br>(0.008)   |   |   | 0.002<br>(0.005)  |
| N   | 29,682  | 29,682  | 29,682  | 29,682  | 29,682  | 29,682  |
| Municipalities  | 2461  | 2461  | 2461  | 2461  | 2461  | 2461  |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$

Table 3.10c: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index – Southeast

| Dependent Variable                                    | Pupil teacher ratio- lower primary<br>(1) | Pupil teacher ratio- lower primary<br>(2) | Pupil teacher ratio- lower primary<br>(3) | Pupil teacher ratio- lower primary<br>(4) | Pupil teacher ratio- lower primary<br>(5) | Pupil teacher ratio- lower primary<br>(6) |
|---|---|---|---|---|---|---|
| <b>Panel A: OLS Results</b>                           |   |   |   |   |   |   |
| Revenue   | -0.039*<br>(0.020)                        | -0.178***<br>(0.053)                      |   | 0.011<br>(0.016)                          | 0.087<br>(0.066)                          |   |
| Revenue*Income per capita - 1 <sup>st</sup>           |   | 0.368***<br>(0.128)                       |   |   | -0.041<br>(0.078)                         |   |
| Revenue*Income per capita - 2 <sup>nd</sup>           |   | 0.162**<br>(0.080)                        |   |   | -0.206**<br>(0.097)                       |   |
| Revenue*Income per capita - 3 <sup>th</sup>           |   | 0.146***<br>(0.053)                       |   |   | -0.084<br>(0.063)                         |   |
| Fundef Intensity                                      |   |   | 0.351<br>(0.450)                          |   |   | 1.373***<br>(0.484)                       |
| <b>Panel B: IV Results</b>                            |   |   |   |   |   |   |
| Simulated revenue                                     | -0.281***<br>(0.050)                      | -0.477**<br>(0.206)                       |   | -0.097<br>(0.080)                         | -0.188<br>(0.120)                         |   |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |   | 1.420***<br>(0.521)                       |   |   | 0.339***<br>(0.140)                       |   |
| Simulated revenue*Income per capita - 2 <sup>nd</sup> |   | 0.464***<br>(0.203)                       |   |   | 0.067<br>(0.138)                          |   |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |   | 0.249**<br>(0.125)                        |   |   | 0.151*<br>(0.081)                         |   |
| Simulated Fundef Intensity                            |   |   | -1.164***<br>(0.553)                      |   |   | 1.883***<br>(0.650)                       |
| N   | 29,682                                    | 29,682                                    | 29,682                                    | 29,682                                    | 29,682                                    | 29,682                                    |
| Municipalities  | 2461                                      | 2461                                      | 2461                                      | 2461                                      | 2461                                      | 2461                                      |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$ .

Table 3.11a: OLS and IV Results: Infrastructure I and Infrastructure II Quality Index – North and Northeast

| Dependent Variable                                    | Infrastructure I Quality Index<br>(1) | Infrastructure I Quality Index<br>(2) | Infrastructure I Quality Index<br>(3) | Infrastructure II Quality Index<br>(4) | Infrastructure II Quality Index<br>(5) | Infrastructure II Quality Index<br>(6) |
|---|---------------------------------------|---------------------------------------|---------------------------------------|--|--|--|
| <b>Panel A: OLS Results</b>                           |                                       |                                       |                                       |  |  |  |
| Revenue   | 0.002<br>(0.002)                      | 0.001<br>(0.003)                      |                                       | -0.011*<br>(0.006)                     | -0.012<br>(0.007)                      |  |
| Revenue*Income per capita - 1 <sup>st</sup>           |                                       | 0.002<br>(0.002)                      |                                       |  | -0.003<br>(0.006)                      |  |
| Revenue*Income per capita - 2 <sup>sd</sup>           |                                       | 0.002<br>(0.002)                      |                                       |  | 0.000<br>(0.006)                       |  |
| Revenue*Income per capita - 3 <sup>th</sup>           |                                       | -0.000<br>(0.003)                     |                                       |  | 0.002<br>(0.005)                       |  |
| Fundef Intensity                                      |                                       |                                       | -0.013<br>(0.008)                     |  |  | 0.010<br>(0.019)                       |
| <b>Panel B: IV Results</b>                            |                                       |                                       |                                       |  |  |  |
| Simulated revenue                                     | 0.040***<br>(0.005)                   | 0.037***<br>(0.006)                   |                                       | -0.075***<br>(0.015)                   | -0.017<br>(0.019)                      |  |
| Simulated revenue*Income per capita -1 <sup>st</sup>  |                                       | 0.007**<br>(0.003)                    |                                       |  | -0.053***<br>(0.007)                   |  |
| Simulated revenue*Income per capita - 2 <sup>sd</sup> |                                       | -0.000<br>(0.003)                     |                                       |  | -0.055***<br>(0.007)                   |  |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |                                       | -0.002<br>(0.003)                     |                                       |  | -0.051***<br>(0.006)                   |  |
| Simulated Fundef Intensity                            |                                       |                                       | 0.109***<br>(0.022)                   |  |  | -0.288***<br>(0.069)                   |
| N   | 20,253                                | 20,253                                | 20,253                                | 20,253                                 | 20,253                                 | 20,253                                 |
| Municipalities  | 1891                                  | 1891                                  | 1891                                  | 1891                                   | 1891                                   | 1891                                   |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates p<.01; \*\* indicates p<.05; \* indicates p<.1

Table 3.11b: OLS and IV Results: Pupil Teacher Ratio – North and Northeast

| Dependent Variable                                    | Proportion of teachers with a degree – lower primary | Proportion of teachers with a degree – lower primary | Proportion of teachers with a degree – lower primary | Proportion of teachers with a degree – upper primary | Proportion of teachers with a degree – upper primary | Proportion of teachers with a degree – upper primary |
|---|--|--|--|--|--|--|
|   | (1)  | (2)  | (3)  | (4)  | (5)  | (6)  |
| <b>Panel A: OLS Results</b>                           |  |  |  |  |  |  |
| Revenue   | 0.002**<br>(0.001)                                   | 0.000<br>(0.001)                                     |  | 0.001<br>(0.001)                                     | 0.001<br>(0.001)                                     |  |
| Revenue*Income per capita - 1 <sup>st</sup>           |  | 0.002**<br>(0.001)                                   |  |  | 0.001<br>(0.001)                                     |  |
| Revenue*Income per capita - 2 <sup>nd</sup>           |  | 0.002***<br>(0.001)                                  |  |  | -0.001<br>(0.001)                                    |  |
| Revenue*Income per capita - 3 <sup>th</sup>           |  | 0.001<br>(0.001)                                     |  |  | -0.001<br>(0.001)                                    |  |
| Fundef Intensity                                      |  |  | -0.002<br>(0.003)                                    |  |  | -0.003<br>(0.003)                                    |
| <b>Panel B: IV Results</b>                            |  |  |  |  |  |  |
| Simulated revenue                                     | -0.001<br>(0.002)                                    | 0.003***<br>(0.001)                                  |  | 0.017***<br>(0.003)                                  | 0.016***<br>(0.002)                                  |  |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |  | -0.008***<br>(0.002)                                 |  |  | 0.000<br>(0.002)                                     |  |
| Simulated revenue*Income per capita - 2 <sup>nd</sup> |  | -0.004***<br>(0.002)                                 |  |  | -0.000<br>(0.002)                                    |  |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |  | -0.001*<br>(0.001)                                   |  |  | 0.002**<br>(0.001)                                   |  |
| Simulated Fundef Intensity                            |  |  | -0.021***<br>(0.005)                                 |  |  | 0.018**<br>(0.009)                                   |
| N   | 20,253   | 20,253   | 20,253   | 20,253   | 20,253   | 20,253   |
| Municipalities  | 1891   | 1891   | 1891   | 1891   | 1891   | 1891   |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$

Table 3.11c: OLS and IV Results: Pupil Teacher Ratio – North and Northeast

| Dependent Variable                                    | Pupil teacher ratio – lower primary<br>(1) | Pupil teacher ratio – lower primary<br>(2) | Pupil teacher ratio – lower primary<br>(3) | Pupil teacher ratio – upper primary<br>(4) | Pupil teacher ratio – upper primary<br>(5) | Pupil teacher ratio – upper primary<br>(6) |
|---|--|--|--|--|--|--|
| <b>Panel A: OLS Results</b>                           |  |  |  |  |  |  |
| Revenue   | 0.259***<br>(0.071)                        | 0.041<br>(0.069)                           |  | 0.070<br>(0.073)                           | 0.092<br>(0.075)                           |  |
| Revenue*Income per capita - 1 <sup>st</sup>           |  | 0.505***<br>(0.060)                        |  |  | 0.069<br>(0.068)                           |  |
| Revenue*Income per capita - 2 <sup>nd</sup>           |  | 0.351***<br>(0.051)                        |  |  | 0.047<br>(0.045)                           |  |
| Revenue*Income per capita - 3 <sup>th</sup>           |  | 0.186***<br>(0.058)                        |  |  | 0.092<br>(0.075)                           |  |
| Fundef Intensity                                      |  |  | -0.624***<br>(0.177)                       |  |  | 0.093<br>(0.181)                           |
| <b>Panel B: IV Results</b>                            |  |  |  |  |  |  |
| Simulated revenue                                     | 0.528***<br>(0.086)                        | 0.021<br>(0.082)                           |  | -0.168**<br>(0.082)                        | -0.365***<br>(0.098)                       |  |
| Simulated revenue*Income per capita - 1 <sup>st</sup> |  | 0.482***<br>(0.081)                        |  |  | 0.188***<br>(0.080)                        |  |
| Simulated revenue*Income per capita - 2 <sup>nd</sup> |  | 0.519***<br>(0.067)                        |  |  | 0.109*<br>(0.057)                          |  |
| Simulated revenue*Income per capita - 3 <sup>th</sup> |  | 0.410***<br>(0.066)                        |  |  | 0.211***<br>(0.09.1)                       |  |
| Simulated Fundef Intensity                            |  |  | 0.770***<br>(0.266)                        |  |  | -0.300<br>(0.328)                          |
| N   | 20,253                                     | 20,253                                     | 20,253                                     | 20,253                                     | 20,253                                     | 20,253                                     |
| Municipalities  | 1891                                       | 1891                                       | 1891                                       | 1891                                       | 1891                                       | 1891                                       |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$



Table 3.12: IV First Stage Results – Math Test Scores 8<sup>th</sup> grade

| Dependent Variable                 | Per capita revenue       |                     |                     |                     |                     |
|------------------------------------|--------------------------|---------------------|---------------------|---------------------|---------------------|
|                                    | Southeast                | South               | North               | Northeast           | Centre-West         |
| <i>Panel A</i>                     | (1)                      | (2)                 | (3)                 | (4)                 | (5)                 |
| Simulated revenue                  | 10<br>(0.077)            | 0.664***<br>(0.003) | 0.673***<br>(0.125) | 0.481***<br>(0.034) | 0.358***<br>(0.087) |
| N                                  | 469,634                  | 123,696             | 79,368              | 429,458             | 53,941              |
| F stat, Excluded Instruments       | 25.15                    | 28.0                | 24.61               | 19.38               | 17.15               |
| Dependent Variable                 | Fundef Intensity         |                     |                     |                     |                     |
|                                    | (1)                      | (2)                 | (3)                 | (4)                 | (5)                 |
| <i>Panel B</i>                     | (1)                      | (2)                 | (3)                 | (4)                 | (5)                 |
| Simulated Fundef Intensity         | 0.716***<br>(0.063)      | 0.869***<br>(0.034) | 0.620***<br>(0.028) | 1.099***<br>(0.174) | 1.231***<br>(0.281) |
| N                                  | 469,634                  | 123,696             | 79,368              | 429,458             | 53,941              |
| F stat, Excluded Instruments       | 21.22                    | 24.55               | 20.81               | 19.90               | 18.88               |
| Dependent Variable                 | Total per capita revenue |                     |                     |                     |                     |
|                                    | (1)                      | (2)                 | (3)                 | (4)                 | (5)                 |
| <i>Panel C</i>                     | (1)                      | (2)                 | (3)                 | (4)                 | (5)                 |
| Simulated total per capita revenue | 0.356***<br>(0.085)      | 0.879***<br>(0.059) | 0.294***<br>(0.100) | 0.400***<br>(0.024) | 0.279***<br>(0.047) |
| N                                  | 469,634                  | 123,696             | 79,368              | 429,458             | 53,941              |
| F stat, Excluded Instruments       | 29.35                    | 25.33               | 27.91               | 27.35               | 38.35               |
| Municipalities                     | 637                      | 380                 | 209                 | 1573                | 202                 |

Notes: Observed revenue and its interactions are instrumented with simulated revenue and its interactions with the same covariates. Clustered standard errors at the municipality-year level in parentheses. All specifications include municipal GDP per capita, population, population age 7 to 15, other municipal revenues, a linear time trend interacted with 1996 primary enrolment and primary enrolment squared, year and municipality fixed effect and municipality specific effects. \*\*\* indicates  $p < .01$ ; \*\* indicates  $p < .05$ ; \* indicates  $p < .1$

Table 3.13a: OLS and IV Results - Student' test scores 8<sup>th</sup> grade

| Dependent Variable          | Math Test Scores  |                      |                     |                     |                    |
|-----------------------------|-------------------|----------------------|---------------------|---------------------|--------------------|
|                             | Southeast<br>(1)  | South<br>(2)         | North<br>(3)        | Northeast<br>(4)    | Centre-West<br>(5) |
| <b>Panel A: OLS Results</b> |                   |                      |                     |                     |                    |
| Revenue                     | -0.001<br>(0.001) | -0.000***<br>(0.000) | 0.002<br>(0.001)    | 0.000<br>(0.001)    | 0.001<br>(0.002)   |
| <b>Panel B: IV Results</b>  |                   |                      |                     |                     |                    |
| Simulated revenue           | -0.008<br>(0.009) | -0.000***<br>(0.001) | -0.009**<br>(0.004) | 0.011***<br>(0.003) | 0.009<br>(0.009)   |
| N                           | 469,634           | 123,696              | 79,368              | 429,458             | 53,941             |

Notes: Robust standard errors in parentheses and clustered at the municipality-year level. All specifications include student's and municipal controls, municipality fixed effects, year fixed effects, as well as a linear time trend interacted with 1996 primary enrolment and primary enrolment squared. \*\*\* indicates  $p < 0.01$ , \*\* indicates  $p < 0.05$ , \* indicates  $p < 0.1$

Table 3.13b: OLS and IV Results - Student' test scores 8<sup>th</sup> grade

| Dependent Variable          | Math Test Scores     |                     |                     |                   |                    |
|-----------------------------|----------------------|---------------------|---------------------|-------------------|--------------------|
|                             | Southeast<br>(1)     | South<br>(2)        | North<br>(3)        | Northeast<br>(4)  | Centre-West<br>(5) |
| <b>Panel A: OLS Results</b> |                      |                     |                     |                   |                    |
| Fundef intensity            | -0.012<br>(0.012)    | -0.047**<br>(0.021) | 0.015***<br>(0.004) | -0.000<br>(0.001) | -0.008<br>(0.007)  |
| <b>Panel B: IV Results</b>  |                      |                     |                     |                   |                    |
| Simulated Fundef            | -0.121***<br>(0.041) | -0.036<br>(0.027)   | 0.011<br>(0.016)    | 0.001<br>(0.002)  | -0.018<br>(0.016)  |
| N                           | 469,634              | 123,696             | 79,368              | 429,458           | 53,941             |

Notes: Robust standard errors in parentheses and clustered at the municipality-year level. All specifications include student's and municipal controls, municipality fixed effects, year fixed effects, as well as a linear time trend interacted with 1996 primary enrolment and primary enrolment squared. \*\*\* indicates  $p < 0.01$ , \*\* indicates  $p < 0.05$ , \* indicates  $p < 0.1$

Table 3.13c: OLS and IV Results - Student' test scores 8<sup>th</sup> grade

| Dependent Variable          | Math Test Scores   |                   |                   |                     |                    |
|-----------------------------|--------------------|-------------------|-------------------|---------------------|--------------------|
|                             | Southeast<br>(1)   | South<br>(2)      | North<br>(3)      | Northeast<br>(4)    | Centre-West<br>(5) |
| <b>Panel A: OLS Results</b> |                    |                   |                   |                     |                    |
| Total revenue per capita    | -0.006*<br>(0.004) | 0.001*<br>(0.001) | 0.004<br>(0.006)  | 0.012***<br>(0.003) | -0.014*<br>(0.008) |
| <hr/>                       |                    |                   |                   |                     |                    |
| <b>Panel B: IV Results</b>  |                    |                   |                   |                     |                    |
| Simulated total revenue     | -0.037<br>(0.081)  | 0.001<br>(0.002)  | -0.014<br>(0.021) | 0.021***<br>(0.007) | 0.016<br>(0.022)   |
| N                           | 255,848            | 65,227            | 47,670            | 239,187             | 28,628             |

Notes: Robust standard errors in parentheses and clustered at the municipality-year level. All specifications include student's and municipal controls, municipality fixed effects, year fixed effects, as well as a linear time trend interacted with 1996 primary enrolment and primary enrolment squared. \*\*\* indicates  $p < 0.01$ , \*\* indicates  $p < 0.05$ , \* indicates  $p < 0.1$

Table 3.14: IV First Stage Results – Educational Attainment

**Panel A**

| Dependent Variable                                       | Total per capita revenue |
|--|--------------------------|
| Simulated total revenue per capita                       | 0.476***<br>(0.047)      |
| Simulated total revenue*GDP per capita -1 <sup>st</sup>  | -0.230***<br>(0.046)     |
| Simulated total revenue*GDP per capita – 2 <sup>nd</sup> | -0.195***<br>(0.054)     |
| Simulated total revenue*GDP per capita – 3 <sup>th</sup> | -0.060<br>(0.039)        |
| N  | 1,128,391                |
| F stat, Excluded Instruments                             | 38.96                    |

**Panel B**

| Dependent Variable                                       | Total per capita revenue*State GDP per capita |
|--|---|
| Simulated total revenue per capita                       | 2.359***<br>(0.288)                           |
| Simulated total revenue*GDP per capita -1 <sup>st</sup>  | -3.043***<br>(0.190)                          |
| Simulated total revenue*GDP per capita – 2 <sup>nd</sup> | -2.209***<br>(0.185)                          |
| Simulated total revenue*GDP per capita – 3 <sup>th</sup> | -1.035***<br>(0.164)                          |
| N  | 1,128,391                                     |
| F stat, Excluded Instruments                             | 103.4   |

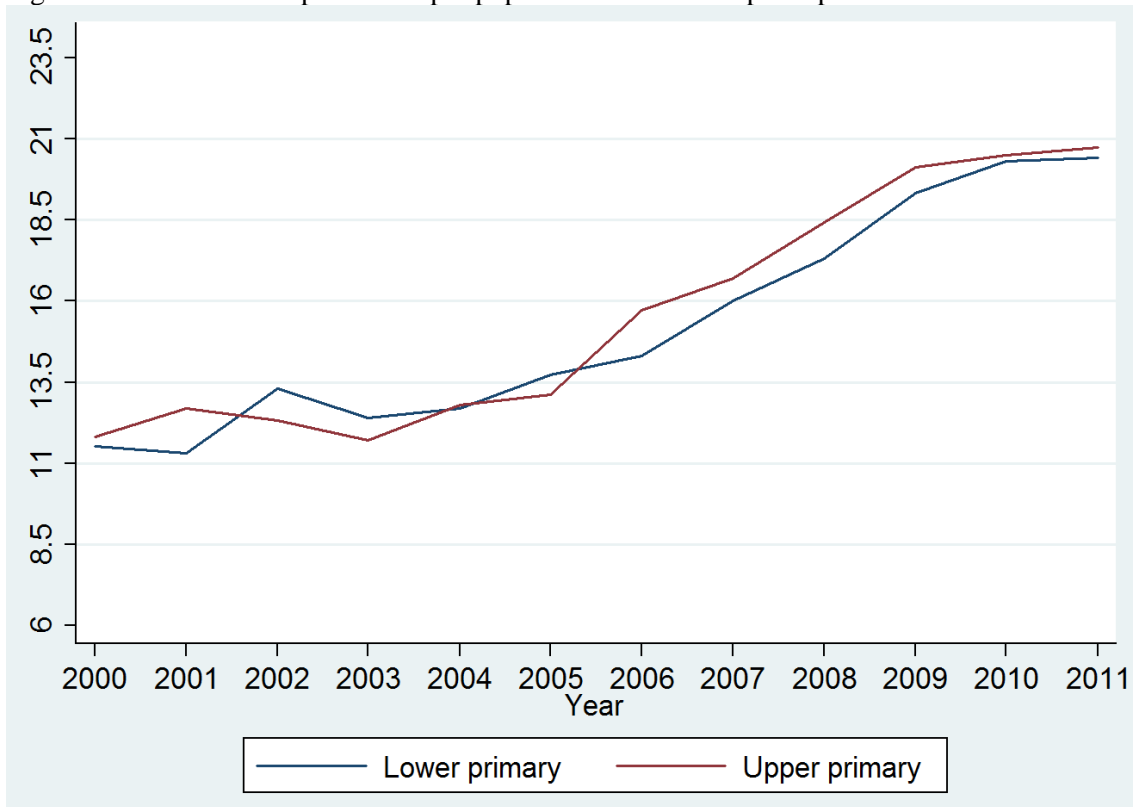
Notes: Robust standard errors in parentheses and clustered at the state-year level. All specifications include individual and state controls, state fixed effects, year fixed effects, state specific effect as well as a linear time trend interacted with 1996 primary/secondary enrolment and primary/secondary enrolment squared. \*\*\* indicates  $p < 0.01$ , \*\* indicates  $p < 0.05$ , \* indicates  $p < 0.1$

Table 3.15: OLS and IV Results: Educational Attainment Outcomes

| Dependent Variable                                       | Attending secondary Education | Primary Education - Complete | Secondary Education - Complete | Years of schooling  |
|--|-------------------------------|------------------------------|--------------------------------|---------------------|
|  | (1)                           | (2)                          | (3)                            | (4)                 |
| <i>Panel A: OLS Results</i>                              |                               |                              |                                |                     |
| Total Revenue  | 0.002*<br>(0.001)             | 0.002<br>(0.001)             | 0.001<br>(0.001)               | 0.005<br>(0.007)    |
| Total Revenue*GDP per capita - 1 <sup>st</sup>           | 0.005***<br>(0.001)           | 0.006***<br>(0.001)          | 0.002***<br>(0.001)            | 0.026***<br>(0.007) |
| Total Revenue*GDP per capita - 2 <sup>sd</sup>           | 0.004***<br>(0.001)           | 0.004***<br>(0.001)          | 0.003***<br>(0.001)            | 0.018**<br>(0.007)  |
| Total Revenue*GDP per capita - 3 <sup>th</sup>           | 0.002**<br>(0.001)            | 0.002**<br>(0.001)           | 0.001<br>(0.001)               | 0.006<br>(0.004)    |
| <i>Panel B: IV Results</i>                               |                               |                              |                                |                     |
| Simulated total revenue                                  | 0.003<br>(0.003)              | 0.003<br>(0.003)             | 0.001<br>(0.002)               | 0.005<br>(0.009)    |
| Simulated total revenue*GDP per capita - 1 <sup>st</sup> | 0.003*<br>(0.002)             | 0.005**<br>(0.002)           | 0.004***<br>(0.002)            | 0.020**<br>(0.009)  |
| Simulated total revenue*GDP per capita - 2 <sup>sd</sup> | 0.003**<br>(0.002)            | 0.003<br>(0.002)             | 0.004***<br>(0.002)            | 0.012*<br>(0.008)   |
| Simulated total revenue*GDP per capita - 3 <sup>th</sup> | 0.002**<br>(0.001)            | 0.002*<br>(0.001)            | 0.001<br>(0.002)               | 0.005<br>(0.005)    |
| N  | 335,601                       | 255,040                      | 314,433                        | 333,709             |

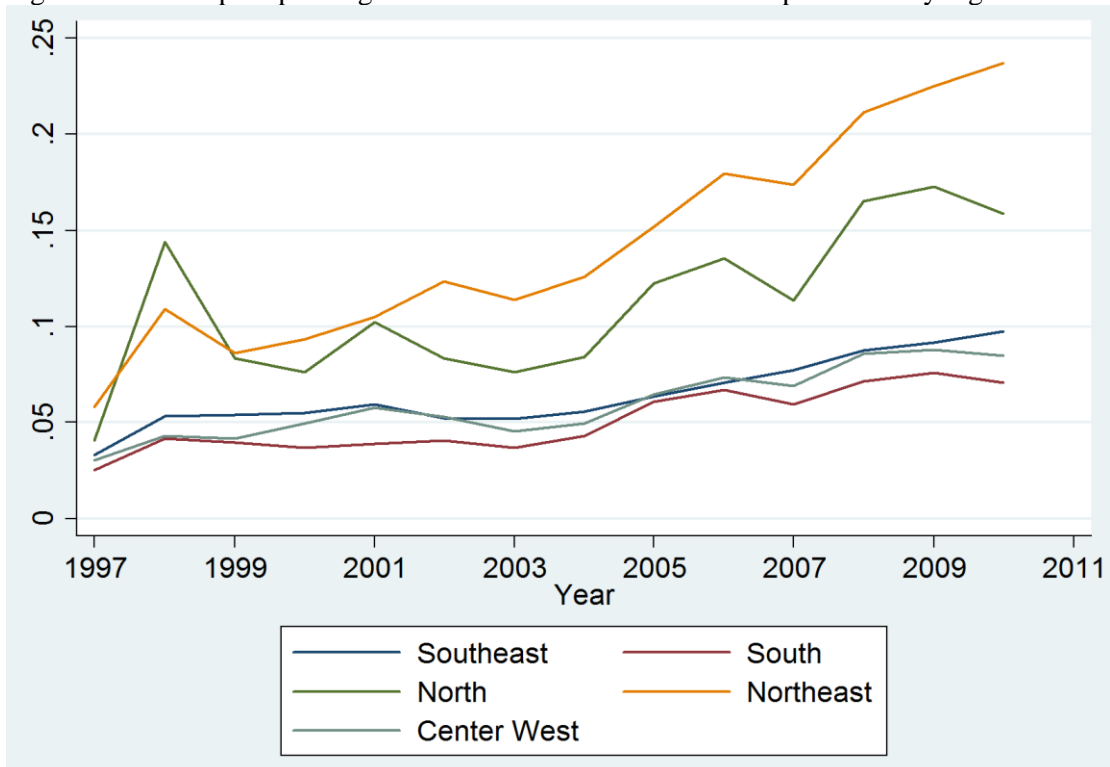
Notes: Robust standard errors in parentheses and clustered at the state-year level. All specifications include individual and state controls, state fixed effects, year fixed effects, state specific effect as well as a linear time trend interacted with 1996 primary/secondary enrolment and primary/secondary enrolment squared. \*\*\* indicates  $p < 0.01$ , \*\* indicates  $p < 0.05$ , \* indicates  $p < 0.1$

Figure 3.1: Education Expenditures per pupil as Share of GDP per capita



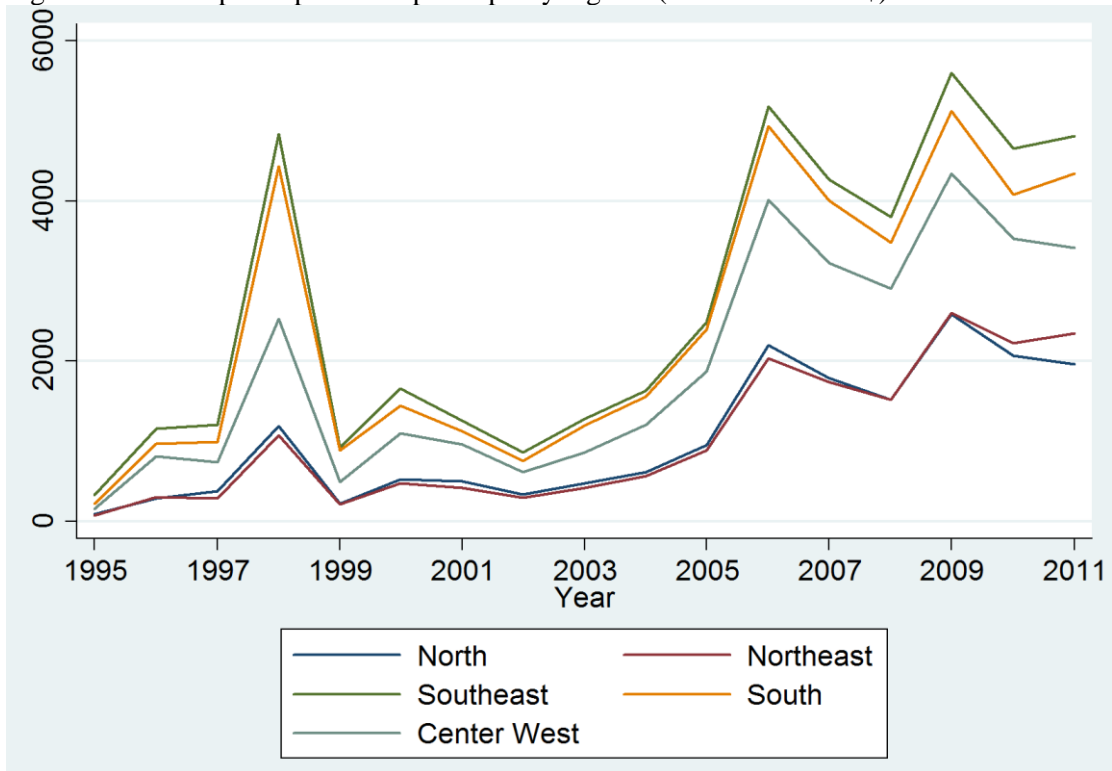
Source: INEP

Figure 3.2 Municipal Spending on Education as a Share of municipal GDP - by regions



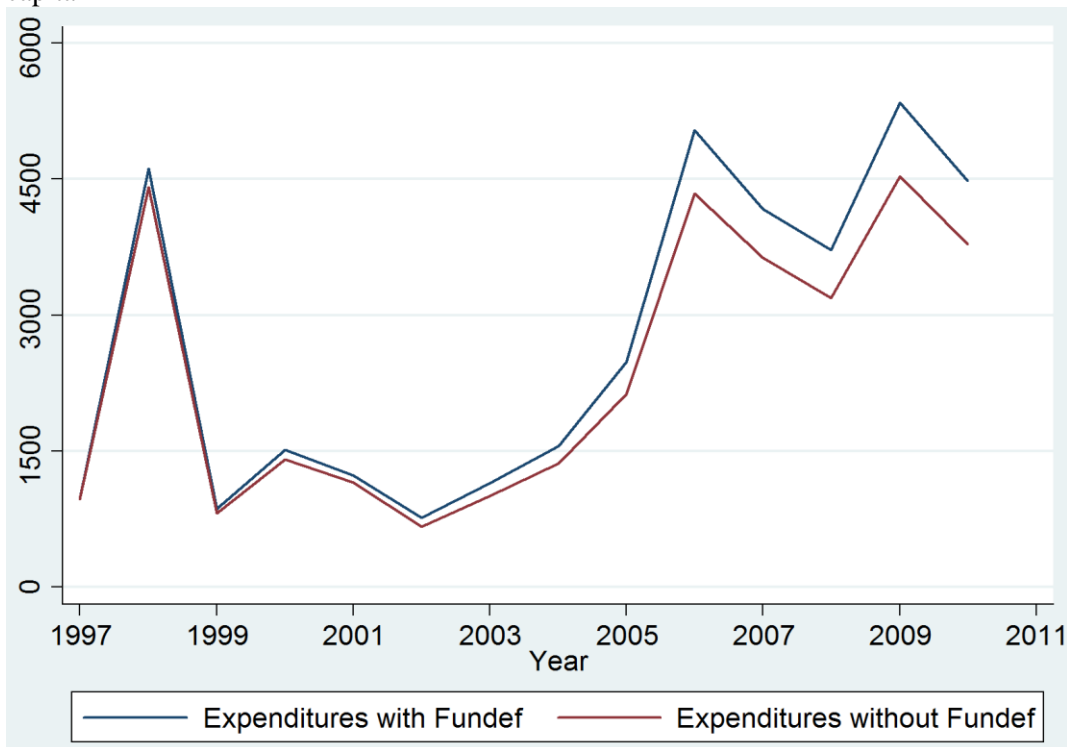
Source: STN and IPEADATA

Figure 3.3 Municipal Expenditure per Pupil by regions (Constant 2011 R\$)



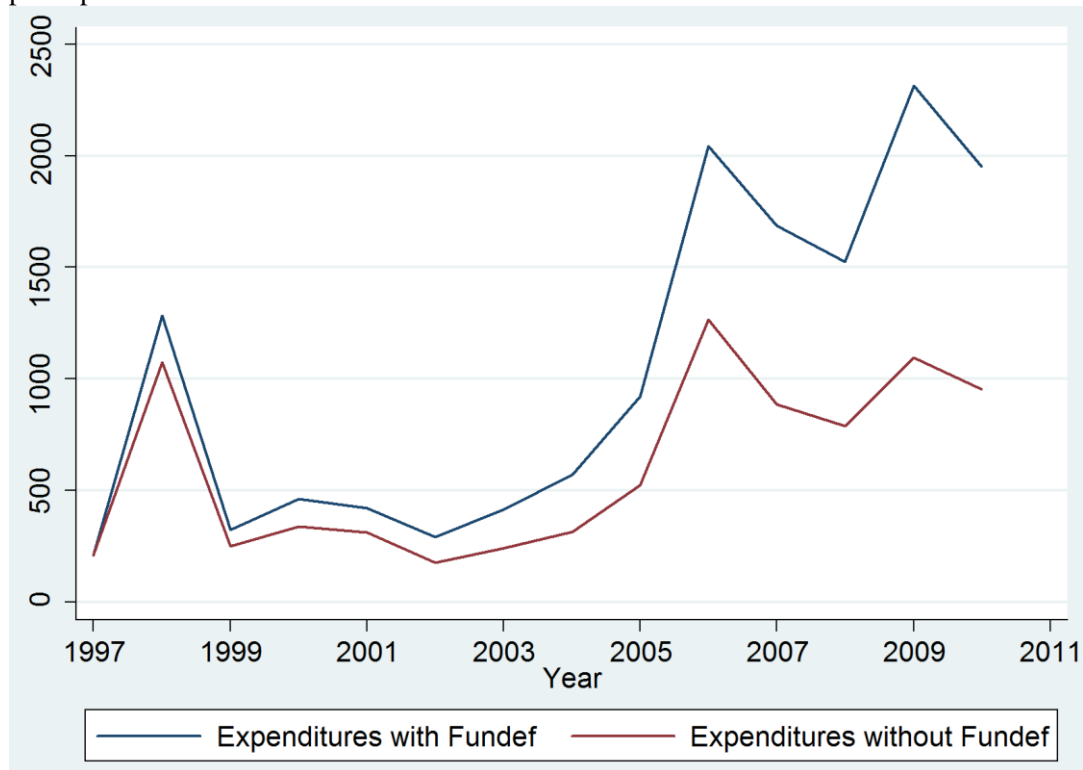
Source: STN and INEP.

Figure 3.4 Real Spending on Education per Pupil - Municipalities in the top quartile of GDP per capita



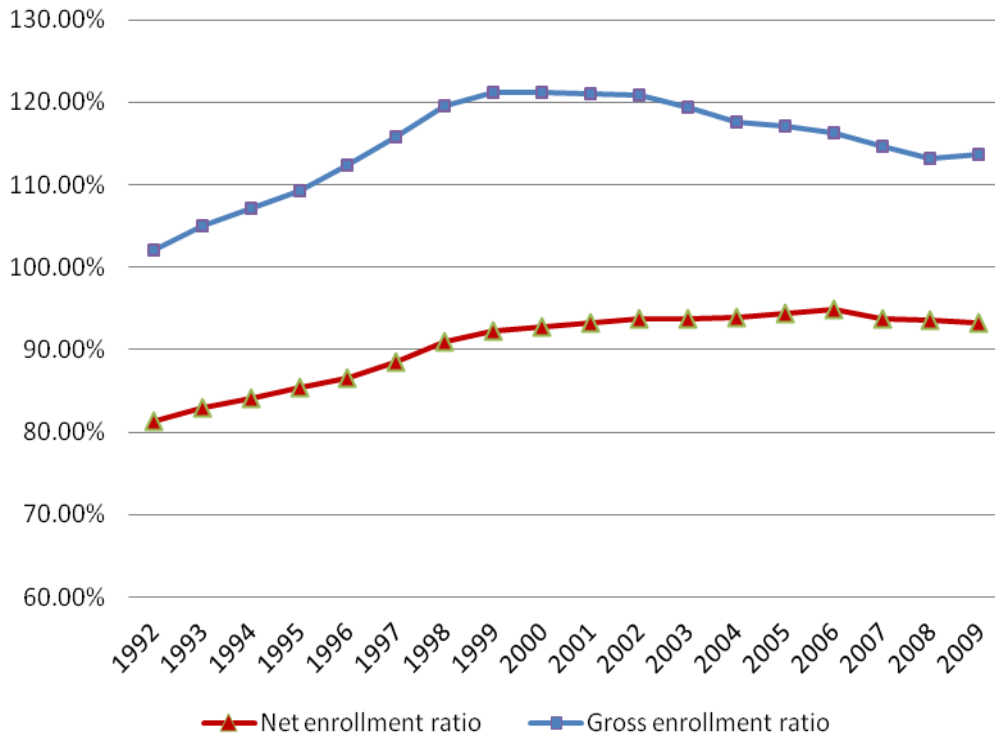
Source: STN and IPEADATA

Figure 3.5 Real Spending on Education per Pupil - Municipalities in the bottom quartile of GDP per capita



Source: STN and IPEADATA.

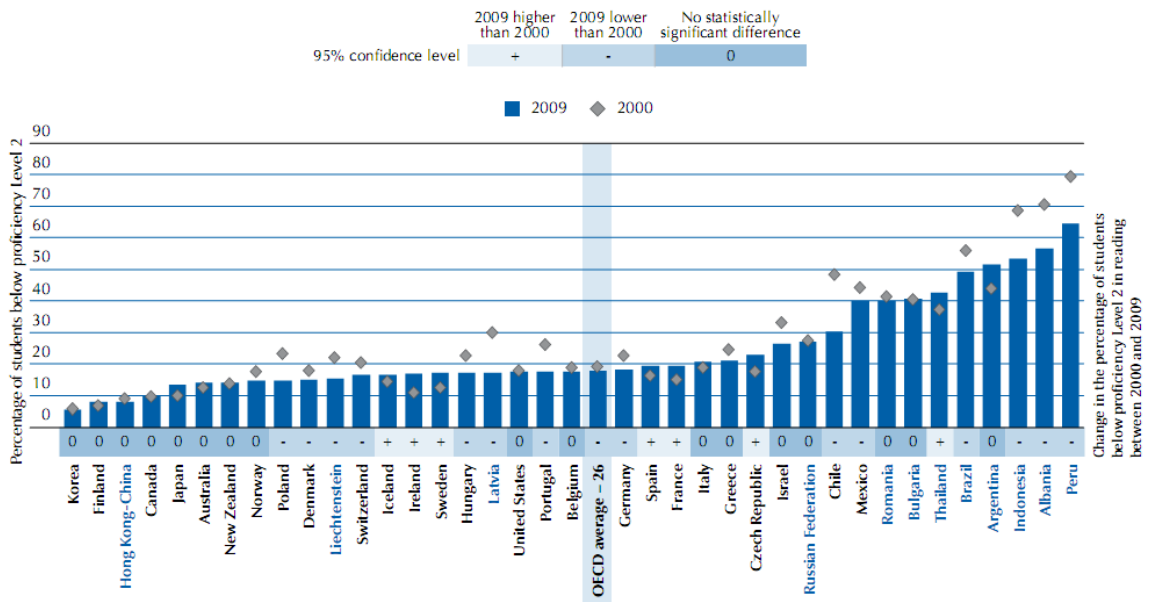
Figure 3.6 Net and Gross enrolment rate - Primary Education



Source: PNAD

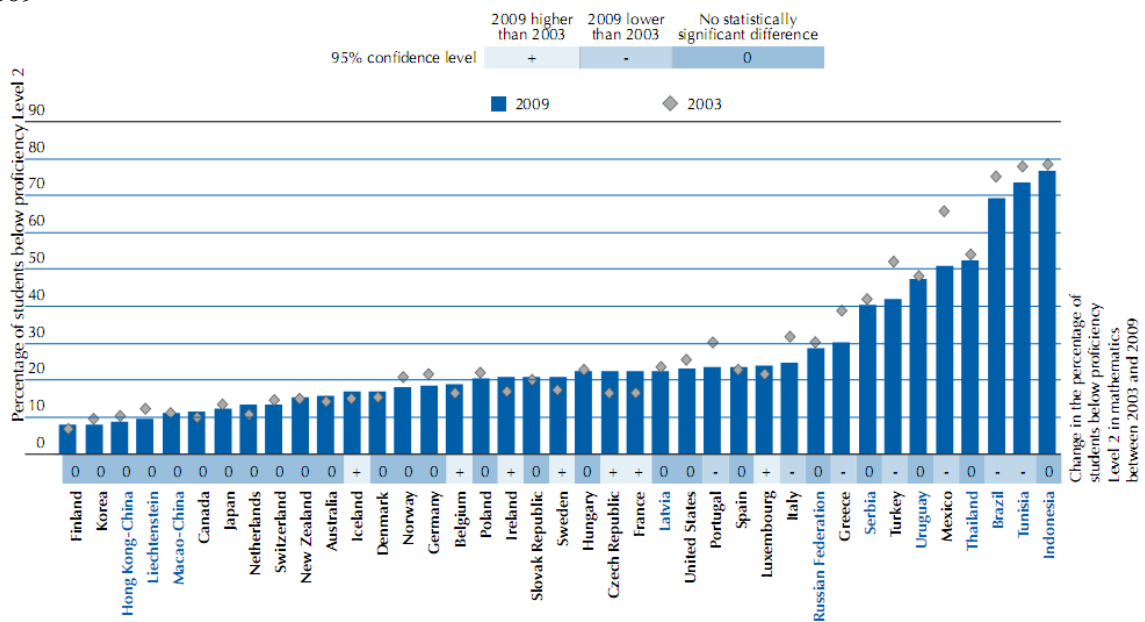


Figure 3.7: Percentage of students performing below proficiency Level 2 in reading in 2000 and 2009



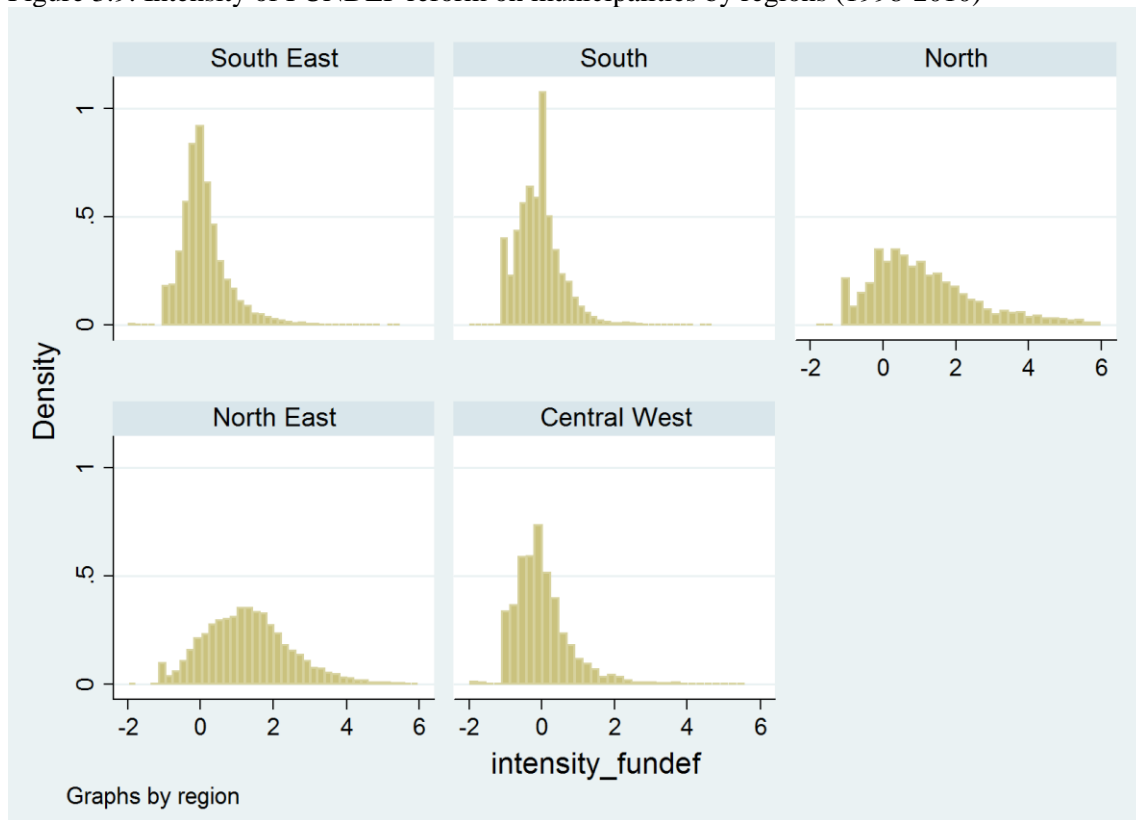
Source: OECD - PISA, 2009.

Figure 3.8: Percentage of students performing below proficiency Level 2 in mathematics 2003 and 2009



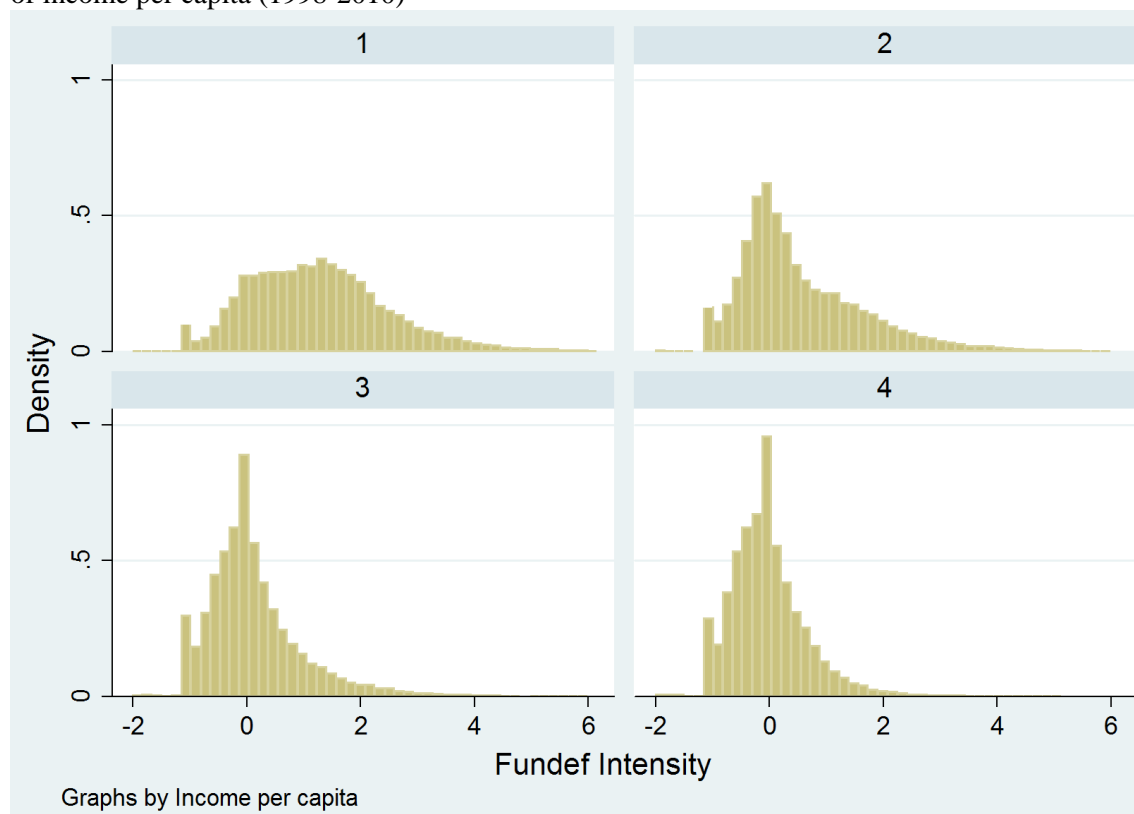
Source: OECD - PISA, 2009.

Figure 3.9: Intensity of FUNDEF reform on municipalities by regions (1998-2010)



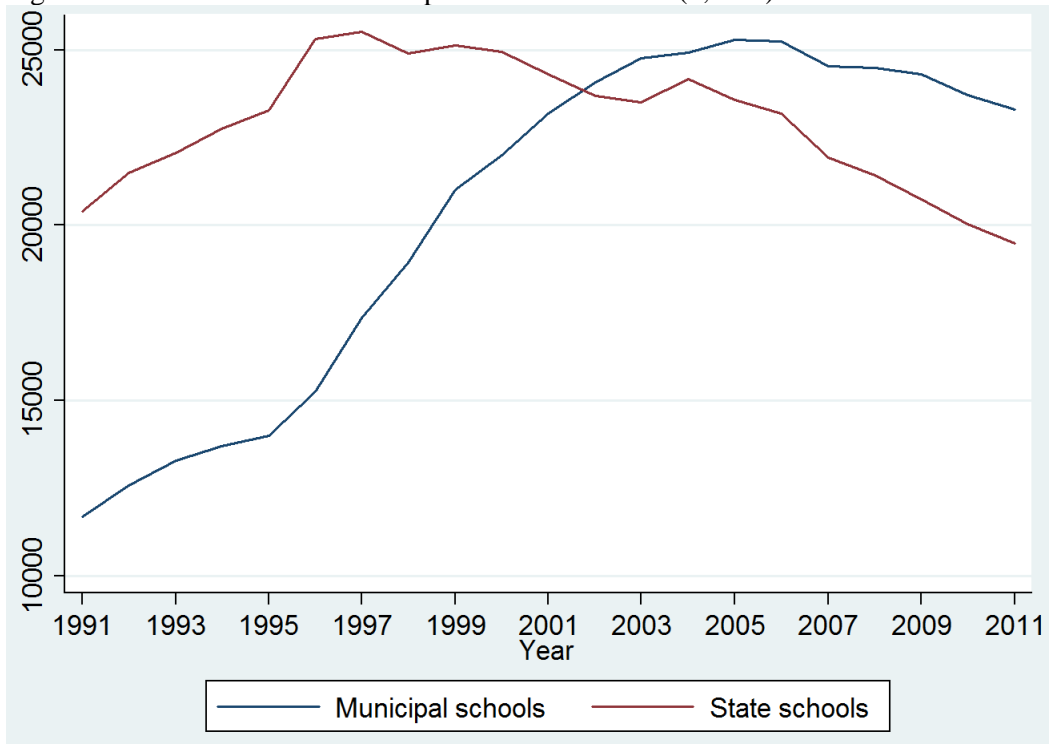
Source: Finbra (Tesouro Nacional)

Figure 3.10: Intensity of FUNDEF reform on municipalities by percentiles (1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup>) of income per capita (1998-2010)



Source: Finbra (STN). 1=First percentile; 2=Second percentile; 3=Third percentile; 4=Fourth percentile.

Figure 3.11: Enrolment rate Municipal and State schools (1,000s)



Source: School Census

## APPENDICES

### A APPENDIX TABLES

Table A.1: Percentage of enrolment considered in each education level - FUNDEF/FUNDEB

| Education Level                      | 1998-2006 | 2007 | 2008 | From 2009 |
|--------------------------------------|-----------|------|------|-----------|
| Pre-primary education                | -         | 1/3  | 2/3  | 3/3       |
| Primary education                    | 3/3       | 3/3  | 3/3  | 3/3       |
| Primary education (Youth and Adults) | -         | 1/3  | 2/3  | 3/3       |
| Secondary Education                  | -         | 1/3  | 2/3  | 3/3       |

Ministry of Education, 2008.

Table A.2: Weighing factor - FUNDEF/FUNDEB

| Education Level  | 1997-1999 | 2000-2004 | 2005-2006 | 2007 | 2008 | 2009 | 2010 |
|--|-----------|-----------|-----------|------|------|------|------|
| Public day care - Full time                                  | -         | -         | -         | 0.80 | 1.10 | 1.10 | 1.10 |
| Public day care - Part time                                  | -         | -         | -         | 0.80 | 0.80 | 0.80 | 0.80 |
| Pre-primary - Full time                                      | -         | -         | -         | 0.90 | 1.15 | 1.20 | 1.25 |
| Pre-primary - Part time                                      | -         | -         | -         | 0.90 | 0.90 | 1.00 | 1.00 |
| Lower primary – Urban  | 1.00      | 1.00      | 1.00      | 1.00 | 1.00 | 1.00 | 1.00 |
| Lower primary – Rural  | 1.00      | 1.00      | 1.02      | 1.05 | 1.05 | 1.05 | 1.15 |
| Upper primary – Urban  | 1.00      | 1.05      | 1.05      | 1.10 | 1.10 | 1.10 | 1.10 |
| Upper primary – Rural  | 1.00      | 1.05      | 1.07      | 1.15 | 1.15 | 1.15 | 1.20 |
| Primary Education - Especial <sup>1</sup>                    | 1.00      | 1.05      | 1.07      | 1.20 | 1.20 | 1.20 | 1.20 |
| Primary Education - Full time                                | -         | -         | -         | 1.25 | 1.25 | 1.25 | 1.25 |
| Secondary Education - Urban                                  | -         | -         | -         | 1.20 | 1.20 | 1.20 | 1.20 |
| Secondary Education - Rural                                  | -         | -         | -         | 1.25 | 1.25 | 1.25 | 1.25 |
| Secondary Education - Full time                              | -         | -         | -         | 1.30 | 1.30 | 1.30 | 1.30 |
| Education Level - Youths and Adults                          | -         | -         | -         | 0.70 | 0.70 | 0.80 | 0.80 |
| Education Level - Youths and Adults (professional education) | -         | -         | -         | 0.70 | 0.70 | 1.00 | 1.00 |

Ministry of Education, 2008. <sup>1</sup>For children with special needs.

## **Chapter 4: Conclusion**

According to Barro (1996), economic growth rate is positively related to schooling. In the OECD area, one additional year of education is estimated to increase economic output by 3 to 6% (OECD, 2005). Improving educational achievement is a policy priority in most countries, with policymakers looking for greater effectiveness and efficiency in the education system.

As pointed out by Card (1999), education plays a central role in modern labour markets. However, despite the extensive availability of data on individual's schooling and income, the literature has not yet reach a consensus on the magnitude of the causal effect of education on earnings.

In the second chapter we aimed at identify regions of returns to schooling in the UK using Manski (1997) and Manski and Pepper (2000) non-parametric bounds. This approach has the advantage to rely on relatively weak and somewhat testable assumptions. The estimates show evidence that the returns to education computed using non-parametric bounds are smaller than some of the point estimates usually reported in the literature, which usually assume somewhat stronger assumptions. This is especially true for higher qualifications.

Debates about how to improve the quality of public education often focus on whether governments should increase education expenditures. The effects of school resources on students' outcome are rather controversial since there is no consensus in the literature about whether increasing school resources improves student achievement.

Little is known about how effective expenditures are at increasing pupil's performance and attainment. A crucial policy matter is, therefore, whether an increase in per pupil expenditure is able to improve students' outcomes. The key question is, thus, whether higher spending translates into student achievements. Identifying the impacts of a higher per pupil spending on educational performance is crucial since it is directly related to the formulation of efficient public policies within the realm of limited resources.

The education funding reform implemented in Brazil (FUNDEF/B) changed the structure of public education funding and was responsible for a large increase in education spending. One of the major goals of the reform was to reduce the large disparities within

and across states, with the ultimate goal of reducing inequalities in terms of students' achievements. Discuss the effects of such a reform is to discuss the issue "Does money matters for education?"

In regards to school inputs, the estimation results suggest a decline in the inequality between poor and rich areas within regions. Overall, the effect of the reform on school inputs seemed to be greater for lower income municipalities, which is quite a desirable result of the policy. This effect could be seen as an important step towards reducing schools' inequalities between poorer and richer areas.

The estimates show no link between educational expenditures and student's test scores. As pointed out by Gordon and Vegas (2005) the reform greatly increase enrolment levels on poorer municipalities. This certainly increased the influx of students with poorer backgrounds on the educational system. However, besides that, the increase in education spending brought by the reform in the period was not able to increase the quality of student's achievement. The results indicate that the increase in educational expenditure did not translate into a higher students' performance in terms of standardized test score, at least in the period analysed. As discussed earlier the literature shows no definite link between education spending and student learning. In the United States, real spending per student more than tripled between 1960 and 2000, but students' performance on standardized tests have remained quite flat (Hanushek, 2003). Chile has also increased its spending on education in the last years, in an attempt to largely improve school quality. Despite that the results for Chilean students on international examinations have remained quite constant. (OECD, 2010).

The results show some evidence of a small but positive effect on educational attainment. The effects seem to be concentrated on low income States, in fact the ones most affected by the reform. The lack of a substantive and a generalized effect on education attainment might reflect the absence of a more substantive and widespread effect on schools inputs and the absence of a positive effect on student's test scores. It may also be driven by selection effect whereby post reforms, more poorer students stay in schools, affecting the average attainment.

The big question remains though, is there a link between education expenditure and school quality? Maybe what the result shows is that higher levels of expenditure per pupil

does not necessarily increase the quality of education that one receives. Maybe what matters most is not directly the amount of money available, but how it is managed and how efficiently it is spent and combined with other practices that could support learning.



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