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Evidence from Brazilian Primary Schools

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Evidence from Brazilian Primary Schools

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This paper analyzes the impact of access to piped water on human capital formation as measured by test scores from standardized school exams in Brazilian primary schools. We find that children in urban areas with access to tap water at home perform significantly better at school: They achieve test scores that are 14 percent of the standard deviation higher than the average test score without access. The effect is conditional on the education of the mother and turns out to be insignificant in rural areas. Our results capture the long term effect of the reduced incidence of water-related diseases for children with access to tap water. We exploit school-specific variation across years as well as a comprehensive vector of socioeconomic background variables to identify this effect.

JEL-Codes: I15, I25, H41

Keywords: Health, piped water, cognitive development, human capital formation

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1. Introduction

700 million people in the developing world lack access to clean water, and around 2.5 billion people have no access to improved sanitation facilities (Joint Monitoring Programme, 2014). Since missing access to improved water and appropriate sanitation facilities seriously compromises health, this situation confines the chances to prosper and to develop full capabilities for more than one third of the world population (ibid.). Lacking access to improved water and sanitation increases the likelihood of water-related diseases such as diarrhea, helminths and malnutrition (Fewtrell et al., 2005; Günther and Fink, 2010; Jalan and Ravallion, 2003), which can have tremendous adverse effects on human capital formation.[1] The eradication of water-related diseases and malnutrition impacts positively on years of schooling, school enrollment, school attendance and literacy of children and young adults (Bleakley, 2007; Bobonis et al., 2006; Miguel and Kremer, 2004). An improved health environment also impacts positively on measures of later economic success such as wages and productivity (Alderman and Behrman, 2006; Baird et al., 2012; Fogel, 1994; Thomas and Strauss, 1997).

While it is thus clear that water-related diseases negatively affect health and human development negatively, more has to be learned about how access to clean water and to improved sanitation facilities can prevent these effects. The above studies, which focus on human capital formation, show that the eradication of water-related diseases through school-based interventions leads to an immediate increase of the time spent in school. They do not study though how access to clean water and improved sanitation affects the cognitive capacities of the children. Cognitive skills have been shown to be crucial for school achievements and later labor market outcomes in the developed world (Case and Paxson, 2008, 2010) and they develop mainly during early childhood (Cunha et al., 2006; Heckman, 2007). Health interventions targeted at school children, although definitely important in order to improve health and learning, can affect this decisive process of development only marginally. The present study investigates the effect of access to tap water on educational achievements of elementary school children. We thereby hope to identify the effect of a healthier environment during childhood on later human capital (formation). While the above literature from developed countries suggests that there may be such an effect, direct

[1] The Joint Monitoring Programme Initiative of the World Health Organization and UNICEF defines improved water access as any type of water source that is protected from outside contamination and is close to the home of users. Improved sanitation is defined as any type of toilet facility that appropriately separates feces from human contact. The exact definition of *improved* access varies from study to study. Cf. Joint Monitoring Programme (2012) and Günther and Fink (2010) for discussions of the definitions.

evidence from developing countries is still missing.

This paper analyzes the effect of access to tap water at home on schooling achievements using pooled data from the school evaluation program *Sistema Nacional de Avaliação da Educação Básica* (SAEB) in Brazil from 1999 to 2005.[2] It provides representative results from standardized tests in mathematics and Portuguese from all over Brazil and complements them with rich information on the socio-economic background of the children's families. These data allow two main contributions to the literature. First, we analyze the relationship between access to tap water and school achievement. This approach has an important advantage compared to other studies that focus on the effect of the eradication of water-related diseases on educational outcomes by health interventions. It allows to capture long-run effects of (lacking) access to clean water. Miguel and Kremer (2004), for example, find considerable positive short run effects of health interventions targeted at water-related diseases on health and school attendance of primary children in Kenya. They find that only half a year after the distribution of deworming drugs, treated children report less incidence of diarrhea and go to school more often. Interestingly though, they find no significant improvement of the test scores of the treated children after one year. That is, the input measure of human capital formation, school attendance, is affected positively, but the health intervention does not affect the output measure of human capital formation, test scores. Yet, ultimately, it is the learning achievement that matters, rather than the time spent at school. One reason for the fact that Miguel and Kremer (2004) do not find effects on test scores may be the short term focus of their study.[3] Health interventions such as deworming may either have only transitory effects on output measures of human capital formation, or the long run effects may take more time to materialize. Baird et al. (2014) further suggest that the intervention was perhaps too late to affect cognitive development. In contrast, our variable of interest measures whether a child has access to tap water at home at the time of the school exam and proxies the current or recent health status of the child. If the current type of access to water is indicative of the past type of access, our variable can also capture long term effects of extended periods of water-related diseases during childhood. If there were substantial changes in the water and sanitation environment of the child during childhood, we would probably underestimate the effect of having access to improved infrastructure as, over time, children are on average more likely

[2] SAEB is called *Prova Brasil!* since 2007.

[3] A complementary study to Miguel and Kremer (2004) by Baird et al. (2014) finds significant and large effects in the long run when comparing treatment and control groups 12 years after the initial intervention. However, their focus is on labor market participation as the by then adult persons left school in the meantime.

to gain rather than to lose access. Our explaining variable thus allows to capture long term effects of reduced incidence of water-related diseases during childhood.[4] Spears and Lamba (2013), the only study that aims at finding comparable effects, show that this can be a promising research design. They match the per capita number of newly constructed pit latrines in Indian districts between 2001 and 2003 to test scores of children in the same district three to six years later. Their results suggest that a healthier early-life environment due to an increased number of latrines in the district improves the children's ability to recognize letters and numbers.

Our second contribution lies within the analysis of the heterogeneity of the effects of access to piped water. As piped water needs a large and expensive infrastructure, it is important to analyze under which conditions the returns to such investments are largest. We study whether the effect of access to clean water is conditional on the educational level of the mother or on income. Heterogenous effects of income and education of mothers have also been found for the impact of tap water access on health outcomes of young children (Gamper-Rabindran et al., 2010; Jalan and Ravallion, 2003).

Whether a child has access to piped water is endogenous to its socio-economic background and the institutional environment of its place of living. We therefore identify the effect of interest using school-specific time effects and a vector of control variables at the child level. The fixed effect setting absorbs unobserved heterogeneity that could lead to systematic differences in access to tap water and school achievement across schools and over time. This addresses, for example, differences in the overall development level of the municipality but also common trends in schooling and infrastructure development or time- and place-specific policy interventions. The covariates at the individual level absorb remaining socio-economic heterogeneity among children from the same school at the child level. With this strategy, we find a very robust effect of around 14 percent of the standard deviation on test scores in mathematics and Portuguese of children living in urban areas. Although eventually we cannot claim causality in a strict sense, our results point to an important relationship, which has not been found in the literature yet. They once again highlight the important distinction of infrastructure supply strategies in urban and rural areas and call for educational support of infrastructure projects also in urban areas.

The remainder of this study is organized as follows. Section two further elaborates on

[4] The drawback of our variable of interest (as compared to health intervention treatment dummies) is that we would need additional information about the actual health of the child at the date of the test and in the past to identify the health channel between access to water and school achievements that the literature suggest. Section 2 will further elaborate on this issue explaining why access to tap water is a valid proxy for health.

the link between access to clean water and educational achievement and describes the situation in Brazil. Section three explains the data we use, and section four presents the results and various robustness checks. Section five addresses effect heterogeneity, and section six concludes.

2. Water, Sanitation & Educational Achievement

2.1. The Effect of Water and Sanitation on Health and Human Capital Formation

We hypothesize that access to tap water affects the educational achievement of young children by reducing the incidence of water-related diseases and thereby improving health. Water-related diseases, such as intestinal worms or diarrhea, are very common in developing countries and especially harmful to young children below five, who also attract them more often than older children or adults. Prüss-Üstün et al. (2008) estimate that 50 percent of all malnutrition of children in developing countries is due to water-related diseases. Glewwe and Miguel (2008) calculate that 17 percent of the healthy years lost by children aged zero to four because of diseases are lost because of diarrhea (12.6 percent) or other nutritional distortions (4.4 percent).[5] Access to improved or even piped water and sanitation very effectively reduces the incidence and duration of water-related diseases by inhibiting fecal-oral transmission of pathogens and thereby improves health significantly (Günther and Fink, 2010; Jalan and Ravallion, 2003; Kremer et al., 2011).

Apart from the acute symptoms, the permanent consequence of chronic malnutrition due to frequent diarrhea and anemia is in particular stunting, a negative deviation from the average height for age. Epidemiological studies such as Guerrant et al. (2002), Checkley et al. (2008), Moore et al. (2001) and Dillingham and Guerrant (2004) show this effect for developed countries, and evidence from randomized experiments starts to confirm this relationship for developing countries as well (Bobonis et al., 2006).[6] Height for age of children below the age of five in turn, which is closely related to cognitive development (Case and Paxson, 2008), causally affects educational attainment and labor market outcomes.[7]

[5] For children aged five to 14, 8.4 percent of the total burden can be explained by water-related diseases. Death is not included into the calculation of healthy years lost.

[6] Bobonis et al. (2006) find that a reduction of helminths infections leads to weight gains of young children in India.

[7] See the reviews by Almond and Currie (2010) and Glewwe and Miguel (2008) and the references therein. Case and Paxson (2008) show that in particular height for age is a proxy of cognitive abilities of young children and that this variable therefore affects many labor market outcomes. See Case and Paxson (2008) for a review on the epidemiological literature with respect to the question why physical growth

In the introduction, we discussed recent evidence from developing countries that finds positive effects of the improvement of health on school attendance (Bobonis et al., 2006; Miguel and Kremer, 2004).[8] The literature on developed countries, however, indicates that the impact of health on educational achievement does not only work through attendance but also through the development of cognitive skills in early childhood, which can be limited by poor health. This study tries to capture this effect by choosing access to tap water as a proxy variable for current and, most importantly, past health status. Recent evidence by Spears and Lamba (2013) endorses this approach.

2.2. Access to Water and Sanitation and Water-related Diseases in Brazil

The present study focuses on Brazil, where the effects of missing access to clean water and appropriate sanitation are still highly relevant. Access to improved water sources is relatively high if compared to developing countries (Joint Monitoring Programme, 2012; Kosek et al., 2003). In the year 2000, the beginning of our sample period, 82.9 percent of all Brazilian households had access to piped water in at least one room of their home (IBGE, 2000). A further 6.5 percent had access to piped water on their premises.[9] However, the national averages hide huge regional and rural-urban disparities, in particular with respect to access to piped water. In rural areas, access on premises was not available for 24.1 percent of all households in 2000. In urban areas, only 3.1 percent of all households used water sources outside their premises. Also with regards to the different regions, the situation was very unequal: In the North, 12.6 percent of the households obtained water from water sources outside their premises and even 17.5 percent in the Northeast. In the Southeast, Center and South of Brazil, it was only 1.7, 2.4 and 2.8 percent respectively. With respect to sanitation, the situation was even worse. In urban areas, 90 percent of the households disposed of a private bathroom, but only 61 percent of these were connected to central waste water collection. In rural areas, only 3 percent were connected to the central sewage network, 35 percent had neither a private bathroom in their house nor on their premises.

The prevalence and distribution of water-related diseases such as diarrhea underlines that access to water and sanitation is still an issue in Brazil and mirrors the unequal

and the development of cognitive abilities are influenced by the same external factors.

[8]There is other literature suggesting an effect of nutrition and health on educational attainment (e.g. Alderman et al. (2006, 2009)), however, it does not directly allow to learn anything about the impact of water-related diseases.

[9]10.6 percent had no access to the central water supply network and obtained their water either from wells or springs on their premises or from tanks, rain water storage or wells or springs outside of their place of living.

distribution of access quite closely. Mendes et al. (2013) report that during the time span from 1995 to 2005, more than 1.5 million infants were hospitalized because of diarrhea and almost 40,000 of them died. In a representative survey by the Brazilian Ministry of Health conducted in 1996, 13.1 percent of all children whose mothers were interviewed had one or several incidences of diarrhea during the 15 days before the interview (PNDS, 2009). In 2006, the end of our sample period, 9.4 percent of the children had diarrhea during the 15 days before the interview. There are large differences according to the underlying water and sanitation situation. 7.8 percent of the children with piped access to the general water network within their houses had diarrhea; without piped access, the rate equaled 13.8 percent. Despite of this situation, several studies show that the absolute and relative numbers of diarrhea have been decreasing considerably during the last two decades pointing to the improvement in access to water and sanitation as the main reason for this decrease (Barros et al., 2010; Mendes et al., 2013; PNDS, 2009).[10] Gamper-Rabindran et al. (2010) link the reduction of child mortality between 1970 and 2000 causally to the expansion of access to piped water in Brazil in the same period.

3. Econometric Approach and Descriptive Statistics

3.1. Data and Research Design

In order to estimate the effects of access to clean water on human capital formation, we use data for the years 1999, 2001, 2003 and 2005 from the *Sistema Nacional de Avaliação da Educação Básica*, the national education evaluation program implemented every two years by the Brazilian Ministry of Education. SAEB contains individual results from nationwide, standardized tests in mathematics and Portuguese in the fourth and eighth grade of the Brazilian *ensino fundamental* and in the third grade of the *ensino medio*. Similar to the majority of the literature on health and school achievements, we focus on the test results from fourth grade, which is equivalent to the fourth grade of European or US primary school: Children are on average 10.8 years old.[11] The sampling strategy of SAEB allows for representative results at the national, rural and urban level and produces a rotating

[10] During the period 1996 to 2006, the use of oral rehydration or similar traditionally produced liquids decreased from 73.4 percent to 60.5 percent among the surveyed population. Oral rehydration is currently the most effective prevention for lethal dehydration from diarrheal diseases. Another preventive measure against diarrheal diseases, the rotavirus vaccine, has only been introduced in 2006 in Brazil. The rotavirus is responsible for around a third of all hospitalizations due to diarrheal diseases in Brazil for children under five, cf. PNDS (2009).

[11] See Glewwe and Miguel (2008) and below for a review of the literature.

school panel. Overall, the sample of fourth graders of all four years contains 9,200 schools and around 12 pupils per school and discipline.[12]

We use test scores as a proxy of human capital as our dependent variable. The tests administered by SAEB are designed such that the test scores of children are comparable across all waves. The exams are primarily meant to test for cognitive capabilities of the children. All questions relate to a specific cognitive capability, such as applying a standard solution technique to a new and/or slightly different problem or drawing a conclusion from a text (SAEB, 2006). Even though the tests aim at measuring cognitive capabilities, also non-cognitive skills of the children, for example their ability to concentrate for a given time or their patience, can influence the test results.[13] We therefore use the test scores as a measure of human capital or simply of educational achievement and not - as suggested by the test design - as a measure of cognitive capabilities.

In addition to the tests, children fill out questionnaires on their home environment and their learning experience at home and at school. We take our main explaining variable from this additional survey which offers two candidate variables to measure the effect of access to clean water and appropriate sanitation. The first question on access to tap water at home was asked in the survey waves of 1999, 2001, 2003 and 2005.[14] It focuses explicitly on *piped* water: In 1999 and 2001 the question was: “Is there piped water (in the place) where you live?”[15], and in 2003 and 2005: “Is there tap water where you live?”. As the questions only asks about the “*place where you live*”, it is not clear whether children state with their answer that there is piped water from a tap within their house or flat, or whether there is piped water in the courtyard, building or plot at home. We also do not have information about whether the water from the tap comes from the central supply, in which case it is likely to be at least treated with chlorine, or from a well or tank on the premises. Whereas the latter is relatively common in rural environments (more than 60 percent of the households use own sources on the premises), only 7 percent of the households in urban areas have access to tap water not stemming from the central system (IBGE, 2000). In

[12] In total, there are around 24 pupils per class in the sample. The test is randomized within schools, i.e. the class which takes the test is chosen randomly if there is more than one class per level. If there are three or more than three classes, two classes are chosen randomly. Within one class, half of the pupils are randomly selected to take the test in mathematics. The other half takes the test in Portuguese. See SAEB (2008) for further details.

[13] Cf. Cunha and Heckman (2007) for a discussion.

[14] 1999 is also the first year of the survey available publicly, in 2007, the design of the questionnaire was changed and the question dropped.

[15] Only the 1999 question contains the words in brackets. See e.g. SAEB (2004) or SAEB (2008) for the documentation of the surveys with all the questions.

other words, this variable may capture two effects: a quality and a quantity effect. The quantity effect stems from having a convenient type of access on the premises. Remote access to water usually translates into smaller consumption volumes, which seems not to affect the quantity of drinking water but the quantity of water used for hygiene and washing dishes or clothes (Ahuja et al., 2010). The quality effect would stem from treatment by the local supplier or smaller risk of pollution during transport and storage (Kremer et al., 2011). We will address this issue in the results section.

The second candidate variable is the number of bathrooms in the place where the child lives.[16] Although the literature summarized in chapter 2 points to equally important and even sometimes complementary effects of access to clean water and appropriate sanitation, we use only the tap water variable as main variable of interest. It is not clear from the question about the number of bathrooms what the children consider to be a bathroom. Especially it is not obvious whether they think a bathroom is a room with a toilet and/or with access to tap water. There is no additional information given to them when the question is asked.[17]

Equation (1) summarizes our econometric approach, where $Water_i$ is the indicator variable indicating the result from the above questions about availability of tap water at home and TS_i is the test score in either mathematics or Portuguese:

$$TS_i = \alpha + \beta_1 Water_i + \boldsymbol{X}_i \boldsymbol{\beta} + \mu_s \times \delta_t + \epsilon_i. \tag{1}$$

As SAEB does not allow to follow individual pupils over time, we look at repeated cross sections of fourth graders controlling for school-specific time effects, where μ_s is the school dummy for school s and δ_t is the time dummy for year t. Since access to water at home is endogenous, the identification of the effect of access to tap water at home on school achievement rests on these school-specific time effects and the control vector $\boldsymbol{X}_i$. The next section will argue that they effectively allow to identify the effect of interest, β_1.

[16] The question is in 1999 and 2001: "How many bathrooms are there where you live?". In 2003 and 2005, it is: "In your home, is there a bathroom?"

[17] We used the bathroom variable as a control variable in some specifications. Whereas overall results point to a significant correlation between test scores and the existence of a bathroom at home and also to complementarities between tap water and the existence of a bathroom, a few coefficients are also negatively significant. This might be an indicator of a negative effect of toilets without tap water for hygienic routines, but it might also be explained by the high probability of measurement error. Results are available upon request.

3.2. Determinants of Access to Clean Water and Identification

Whether a child has tap water at home depends on determinants of water supply at the relevant jurisdictional level and on its personal background. First, the municipality where the family lives has to dispose of a functioning distribution network for fresh water that connects all neighborhoods to the network. According to the Brazilian Constitution, the main responsibility for operation, maintenance and expansion of networks lies with the municipalities. However, the municipalities may give concessions to regional or private firms. In 2000, 48.4 percent of the municipalities were served exclusively by state-owned enterprises (SOE) operating at the level of the federal states, so-called regional providers. The municipalities that were not or not exclusively covered by the regional SOE either took care of provision on their own (25 percent), had shared responsibilities with a regional provider (21 percent) or gave concessions to local consortia of several municipalities or to private entities (3.8 percent, all figures from PNSB (2000)). Second, the financing of large infrastructure projects depends on additional municipal, state or even federal funds (World Bank, 2001). Access to piped water is therefore a function of the financial capacity of the relevant bodies, of the institutional quality and of governance and also of the interplay of the different levels of decision making. The quality and financial capacity of governmental institutions are also decisive for the quality and endowments of schools and therefore at least in part also for the achievement of pupils.[18] The school dummies in the above specification control for all time-invariant heterogeneity between municipalities, states or regions that could be the reason for differences in piped water access and schooling achievement at the school level. These may be differences in development stages or financial resources, but also differences in the priorities of local governments for communal development, or the level of ownership of the infrastructure.

Only 2 percent of the Brazilian municipalities in 2000 did not have any piped water supply network but 11 percent reported that the network was not available in parts of their municipality (PNSB, 2000). Therefore, the capacity or willingness at the local level to connect all neighborhoods in the municipality is particularly important in the present setting.[19] As we use dummies at the school level, we do not only control for differences at

[18] Ferraz et al. (2012) report that 85 percent of all primary schools in Brazil are managed by the municipality. Monetary resources come from municipal and state governments and also from federal funds, but municipalities are in charge of spending them. The National Council of Education decides about the curriculum. See also: Plank (1990) or Brown (2002).

[19] Informal and/or illegal settlements can be e.g. favelas or loteamentos. Willingness to supply services especially in loteamentos is often linked to zoning and lot size regulations. See Feler and Henderson (2011) and World Bank (2001).

the municipality level but also for potentially different attitudes of municipal or regional policy makers and institutions towards public good provision in specific areas, as for example informal or illegal settlements. This type of unobserved heterogeneity is absorbed by the school dummies as long as the school is located in a specific area or a considerable part of its pupils come from such an area to the school. Since we interact the school dummies with year dummies, we also account for heterogeneity at the various levels across years. For example, policy reforms or attitudes in a particular place in a given year may lead to measurable differences in access to water and quality of schooling in between the two-year intervals of the SAEB waves. The school-year fixed effects also capture a likely positive trend in infrastructural and educational improvement over time.

The second determinant for children's access to piped water at home is the socio-economic situation of their families. If connection to the network is in principle available, the family can decide to get connected and bear the costs for piped water consumption and possible connection fees. If connection to the network is not feasible in the current place of living, the family has to decide about moving to a connected neighborhood. The willingness to connect or to move to connect, is a function of a family's financial capacities, its awareness of the importance of access to piped water, its awareness of the consequences of water-related diseases especially for children and its valuation of child health. Obviously, all of these aspects can also impact on the family's child achievement at school. For example, the financial situation of the family is decisive for the capacity to pay for piped water access, but also for supporting a child with pedagogical material or with additional private teaching. In the same way, a better educated mother is likely to know more about water-related diseases and to be able to better support her child in learning for school.

Glewwe and Miguel (2008) list health status, parental inputs (such as school supplies, books and quality time spent with the child) and the innate ability of the child as main determinants of academic skills. Further determinants are school and teacher characteristics as well as years spent in school. While school and teacher characteristics are absorbed by the time-specific school effects[20], the learning environment and further parental inputs may substantially differ from one child to the other.[21] Especially the educational level of the mother has been shown to impact significantly on the learning productivity of children (Behrman et al., 1999).[22] Attanasio et al. (2012) and Banerji et al. (2013) show in random-

[20]Note that this also takes into account the water access and sanitation equipment of the schools and also, for example, whether the school is in an urban or rural area (cf. Orazem and King (2008)).

[21]Glewwe and Kremer (2006) survey the empirical literature with respect to empirical determinants of schooling attainment (attendance and test scores), Murnane and Ganimian (2014) with respect to test scores.

[22]Studies from OECD countries show that also the fathers' educational level matters (Behrman and

ized experiments that teaching mothers in literacy and on how to improve the interaction with their toddlers or later the learning environment increases test scores of the children significantly. However, also the mere presence of parents impacts positively on schooling success. Evans and Miguel (2007) find that children whose parents died perform significantly and permanently worse at school. The income or opportunity costs of spending time at school or learning at home have also been shown to matter for schooling success of children (Orazem and King, 2008). Plug and Vijverberg (2003) differentiate between the genetic transfer of innate ability and the effect of wealth of the parents by decomposing schooling attainment of own and adopted children within the same family. They find that wealth explains half of the variation in different attainment measures. With respect to the opportunity costs of time, Gunnarsson et al. (2006) show that test scores of third and fourth graders in Latin American countries decrease by around 7 percent if the children report to work before or after school outside their home.[23] In order to control for the various aspects of child-level heterogeneity that may confound the estimate of interest, we use several variables from SAEB that describe the socio-economic situation of families. In particular, we use data about the educational level of the parents and an household wealth indicator as well as dummies indicating whether a child lives with its parents, whether the parents have books and electricity at home and whether the child works before or after school. The next section gives summary statistics and further details with respect to these variables.

Overall, the use of time-specific school effects and the vector of additional control variables at the individual level account for substantial variation across municipalities, schools and families that could drive the access type to water as well as school achievements of children. Due to the school-specific time effects, the variation in the explaining variable that we exploit is only within groups of around 12 pupils in specific schools and years. If there are two classes sampled from one school, variation is within groups of 24 pupils. All differences in socio-economic backgrounds of the children within one group are additionally absorbed by the individual controls. We are therefore reasonably sure to identify the effect of access to clean water on human capital formation. The results and further robustness checks below will further back up this assumption.

Rosenzweig, 2002).

[23] Cf. Kis-Katos and Schulze (2011) for a discussion of possible channels.

3.3. Descriptive Statistics from SAEB, 1999 to 2005

On average, 89.7 percent of the children in the sample that we use have access to tap water. However, there are large intertemporal and regional differences. Table 1 gives an overview. It shows the traditional differences between the rather rich regions South-East and South and the rather poor North and North-East in Brazil. In the richer regions, almost all children answer that they have tap water at home in 2005, in the poorer regions only about 85 percent of the children state the same in the same year. As expected, access increases over time but unevenly across the regions and over time. Especially the 2001 wave shows some peculiarities: First, in three out of five regions, access is reported to be lower than in 1999. Second, the jump from 2001 to 2003 is considerably larger in South-East, South and Center. There have been some changes in the sampling strategy between the 2001 and the 2003 wave, however, none of these changes could in our opinion explain the pattern in Table 1.[24] This raises concerns of comparability of the four waves. We will run robustness checks to address these concerns.

Table 1: Regional and Intertemporal Differences in Water Access

	North	**North-East**	**South-East**	**South**	**Center**	**∅ per Year**
1999	0.777	0.829	0.892	0.917	0.879	**0.867**
2001	0.805	0.805	0.879	0.909	0.886	**0.856**
2003	0.836	0.836	0.975	0.983	0.947	**0.920**
2005	0.851	0.877	0.987	0.988	0.953	**0.941**
∅ per Region	**0.820**	**0.836**	**0.933**	**0.951**	**0.916**	

Notes. The table shows average access to tap water at home by region and year with data from SAEB 1999 to 2005. The last column and row show the average access rates per year and region, respectively.

Figures 1, 2 and 3 plot the cumulative density of access rates per school for different samples. Figure 1 shows that around 55 percent of all schools have access rates below 100 percent and that there is therefore enough variation in the explaining variable within schools. We thus can use school fixed effects to exploit this variation. Figure 2 depicts the rural and urban divide in access rates. Figure 3 shows the distribution for the four waves. Again, the 2001 wave is different from the three others. Especially, the density above the access share of 60 percent seems to be considerably higher than in the three other waves.

Table 2 shows descriptive statistics about the socio-economic background of the children and their families. It distinguishes between children at rural and urban schools. The first column of the rural and urban sections gives the sample means for all children at these schools. The second and third column show summary statistics for the samples of children

[24]See section 4.2 for details on the sampling strategy differences.

Table 2: Descriptive Statistics, Fourth Grade, 1999-2005

Panel A: Distribution of Binary Variables

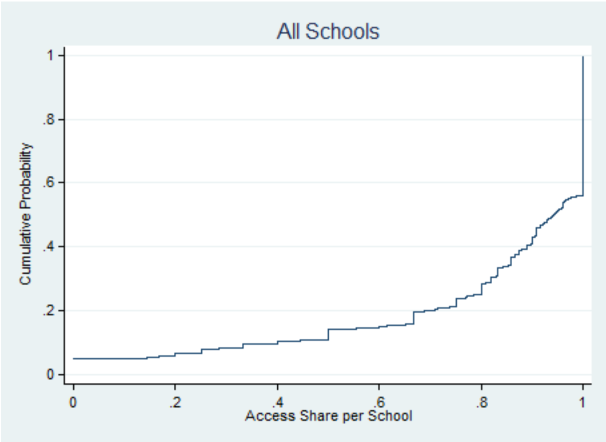
	Urban			Rural		
	All	**w/o Water**	**w/ Water**	**All**	**w/o Water**	**w/ Water**
European	0.43	0.37	0.43	0.34	0.29	0.37
Mulatto	0.40	0.42	0.40	0.45	0.45	0.45
Black	0.11	0.14	0.10	0.15	0.20	0.13
Asian	0.04	0.04	0.03	0.03	0.03	0.03
Indigenous	0.03	0.03	0.01	0.03	0.02	0.03
Mum_noeduc	0.05	0.09	0.05	0.13	0.20	0.11
Mum_primary	0.26	0.31	0.26	0.44	0.42	0.44
Mum_secondary1	0.19	0.19	0.19	0.12	0.10	0.13
Mum_secondary2	0.11	0.08	0.12	0.05	0.03	0.06
Mum_university	0.12	0.07	0.13	0.03	0.02	0.03
Dad_noeduc	0.06	0.10	0.05	0.16	0.22	0.14
Dad_primary	0.20	0.25	0.20	0.32	0.30	0.34
Dad_secondary1	0.15	0.15	0.15	0.10	0.07	0.11
Dad_secondary2	0.10	0.06	0.10	0.04	0.03	0.04
Dad_university	0.12	0.07	0.13	0.02	0.01	0.03
Electricity	0.97	0.89	0.98	0.85	0.71	0.92
Child works	0.15	0.25	0.14	0.38	0.44	0.35
Books at home	0.82	0.77	0.83	0.74	0.67	0.78
Observations	115,802	8,490	107,312	9,452	2,861	6,591

Panel B: Distribution of Continuous Variables

	Urban			Rural			All		
	All	**w/o Water**	**w/ Water**	**All**	**w/o Water**	**w/ Water**	**Min**	**Max**	**Mean**
Age	10.73	11.13	10.70	11.44	11.81	11.26	8.0	15.0	10.8
Test score	186.63	170.54	188.01	160.35	154.68	163.12	66.7	373.4	184.0
Wealth	0.21	-0.59	0.28	-1.75	-2.53	-1.37	-4.86	7.13	0.01
Observations	115,802	8,490	107,312	9,452	2,861	6,591	125,254	125,254	125,254

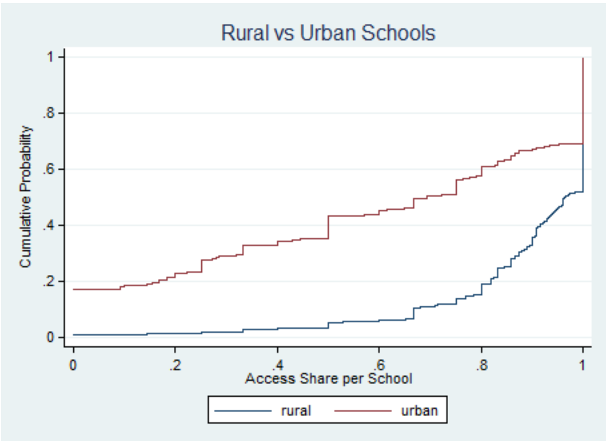
Notes. The table shows in Panel A the distribution of indicator variables (ethnic group, educational level of mother and father, electricity access, child works at home or outside, having at least one book at home) according to the area (urban/rural) and to tap water access (w/o Water, without tap water access at home; w/ Water, with tap water access at home). The educational levels are no education, completed primary school (4 years), completed secondary school (8 years), completed secondary school 2 (12 years), and completed university. The left out category is the answer: "I do not know the education level of my parents". Panel B shows the mean values of age, test scores (overall) and wealth for the urban, rural and total sample.

Figure 1: Access Rates per School, Total Sample



Notes. This figure shows the frequency of access rates to piped water per school in increasing order of access rates. All schools and classes from 1999, 2001, 2003 and 2005 are used.

Figure 2: Access Rates per School, Rural vs. Urban



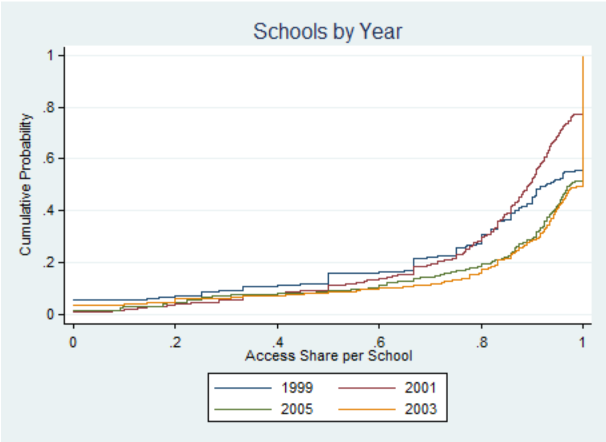
Notes. This figure shows the frequency of access rates to piped water per school in increasing order of access rates in rural and urban areas separately. All schools and classes from 1999, 2001, 2003 and 2005 are used.

with and without access to tap water at home. Panel A summarizes indicator variables, panel B continuous variables.

All indicators of socio-economic background and child characteristics differ significantly between the rural and urban sample. Fourth graders are older and have worse test results in rural areas. Urban parents are on average better qualified, they have better infrastructure and their children work less often before or after school. In rural areas, especially families from European descent have a higher probability to have tap water access at home.

Splitting the sample into children with access to tap water and children without tap water at home reveals that these two groups have quite different family backgrounds in

Figure 3: Access Rates per School and Year



Notes. This figure shows the frequency of access rates to piped water per school and in increasing order of access rates. All schools and classes from each year are used.

rural and in urban areas. Children with access to tap water are younger in both areas and their test scores are better. Electricity is better available than tap water: Even 89 percent of the children without tap water at home report that there is electricity at home. In rural areas, electricity coverage is lower and the difference between both sub-samples is larger. Mothers in families with piped access to drinking water are better educated than mothers of families without access to tap water at home. This is also true for fathers. 25 (44) percent of the children without water access in urban (rural) schools work before or after school. These shares are considerably lower for children with access to piped water. When asked whether their family disposes of books at home (at least 20 books), 77 percent of the urban children without water access say yes as compared to 83 percent of the children with water access. In rural schools, the difference is again larger.

The last variable in Table 2, "Wealth", proxies for long term wealth of the families. As we do not observe true income or wealth of the children's families but a number of variables proxying for the economic situation of the families, we construct a long term wealth proxy from these variables using principal component analysis.[25] We use the following items to construct the long term wealth index: household size, persons per room, domestic help, number of cars, existence of TV, radio, video, PC, fridge, freezer, vacuum cleaner and/or cloth washer. This choice of variables for the principal component analysis probably reflects wealth at a relatively high level, i.e. the underlying variables do rather portray differences in wealth of non-poor families than differences in wealth between poor and non-poor families.

[25]See McKenzie (2005) or Filmer and Pritchett (2001) for the first contribution in this area, cf. also Kolenikov and Angeles (2009)

However, variables that are usually used to depict poverty, such as the type of housing or walls or the existence of public illumination in the neighborhood, are not available from SAEB. Tables A.1 and A.2 in the appendix show the results of the principal component analysis. According to the eigenvectors, the first principal component seems to embody the differences in overall wealth across families: All variables but household size load positively on the first component. As the overall economic situation of families most likely drives the probability to have access to piped water at home as well as the schooling achievement of children, the first component is most suited to control for as much latent information about wealth differences as possible. All the following components could capture the structure of the differences in wealth.[26] Table 2 shows that the first principal component captures considerable variation in our sample. The means are significantly different between all sample splits.

4. Results

4.1. Socio-economic Background of the Parents

Table 3 presents baseline results for test scores in mathematics (columns 2-6) and Portuguese (columns 6-12) explained by control variables that we include in all of the following regressions.[27] Some of them are predetermined, but as shown in the descriptives, all of them may capture cross-sectional heterogeneity with respect to the socio-economic status of the household of the child. In all specifications, we standardize the test scores to mean zero and standard deviation one to make coefficients comparable. Error terms are clustered at the school level to allow for correlation between pupils from the same school.

The first four variables account for the ethnic background of the pupil. European descent ("white") is the omitted category. Being black or from the indigenous community is signif-

[26]According to the signs of the eigenvectors, the second component could capture the variation between items that are more basic (persons per room, TV, freezer, cloth washer) and items that are more sophisticated or judged less decisive in daily life (freezer, video, vacuum cleaner, car, domestic help or persons per household). The interpretation of the third and following components is less evident. Using the general decision rules on how many components to include in our final regression, we will later also use the second and third component of the principal component analysis presented here as robustness checks. The eigenvalues of the first three components are above one and the screeplot breaks after the third component. Together, the first three components explain 50 percent of the total variation. The nine remaining components explain between 3 and 6 percent of the variation each and thus might be noise.

[27]In order to reduce table size, we show these coefficients only here. Unless otherwise mentioned, the coefficients of these variables do not change in magnitude or significance in the following specifications.

icantly negatively correlated with schooling results as compared to the reference category. Next, we control for age and sex of the children.[28] In column 2, we add our variable of interest. Having access to tap water at home turns out to be positively and significantly related to test scores. Columns 3 and 4 introduce school fixed effects and school-specific time effects and thus control for all the time-specific heterogeneity in policies, attitudes and development stages in the municipality and school cross-section. They also control for common trends in the dependent and the explaining variables. The coefficient estimates of interest reduces heavily but remains highly significant in both specifications. If taken (prematurely) to be causal, access to tap water at home explains around 15 percent of the standard deviation of test scores. Murnane and Ganimian (2014) review the literature about the determinants of test scores and report positive effects in the range of five to 59 percent of the standard deviations in primary schools. The reviewed interventions range from prolonging the school day (five percent) to building a new school in the village to avoid traveling costs for children (59 percent). Interventions such as providing eye glasses or school meals to children or improvements of the learning environment at home through training of mothers yield average increases of test scores of 15 to 20 percent of standard deviations. Against the background of these findings, the magnitude of the estimates of the effect of better health through access to tap water are reasonable and not out of scope.

The last columns of table 3 control one after the other for the variables that may determine schooling attainment and access to tap water simultaneously (see section 3.2 for discussion). First, we include the indicator variable for electricity. On one hand, electricity is crucial to learn for school during evenings, on the other hand, the availability of electricity may also capture the general level of public goods provision in the neighborhood of the child. Additionally, we add the wealth proxy in columns 6 and 12. The fact that we can distinguish water, electricity and wealth effects separately and that the water coefficients only slightly changes, gives us a first reason to believe that an omitted variable bias linked to the socio-economic background of families is less of an issue in our context. This result will be reinforced by the following specifications in table 4, which control additionally for other strong indicators of the socio-economic background of the families by adding more measures of ability and economic success of the parents.[29]

[28] Age is correlated significantly negative with test scores. This result is counter-intuitive at first sight. Especially during the first years at school, age has been reported to impact positively on school achievements. In a variation of this first baseline regression (not shown), we included dummies for each age category. Whereas children aged 7-12 perform significantly better than the omitted category (aged 6), children older than 12 perform significantly worse than their younger class mates. In the specification underlying table 3, this negative effect seems to outweigh the positive one.

[29] As the results from Portuguese and mathematics tests are very similar with respect to coefficient mag-

First, we add the highest educational level of the mother. Every educational level of the mother is positively related to children's test scores when compared to non educated mothers. Fathers' education turns out to be mostly insignificant.[30] The educational variables proxy not only for the socio-economic background of the family but also for the potential awareness of the parents of water-related diseases, their consequences and how to treat them. The next variable we include indicates whether a child works at home or outside the parental house before or after school and therefore has to contribute to either the household's income or has to substitute for a help that the household cannot afford. This is correlated negatively and highly significantly to test scores. The last variable in table 4 indicates whether the child thinks that there are more than 20 books at home.[31] The sample size is now considerably smaller as this variable is not available for 1999. The correlation is positive and significant. Even though we have included many strong indicators of socio-economic backgrounds of the children, the coefficient of tap water at home remains highly significant throughout all specifications and does only slightly alter in magnitude. If an omitted variables bias due to the socio-economic background of the parents was an issue here, we would have expected our estimate of interest to be sensitive to the inclusion of the above control variables. As it stabilizes at around 11 percent of the standard deviation, this seems not to be the case. We will use the specification of column 4 of table 4 as our preferred specification for comparison in the following robustness checks. It includes all important controls for the socio-economic background of the children and the time-specific school dummies and allows to keep all four years in the underlying data set.

nitudes and significances, we only present results for mathematics tests in the following. All results for Portuguese scores are available on request.

[30]The question for parents' education contains the category "I do not know", which shows to be significantly and positively correlated to test scores for mothers' and fathers' education. One possible explanation could be that children with higher school achievements check the "I do not know" category more often than children with lower test scores who leave this question unanswered because the former understand better what the "I do not know" category is supposed to mean whereas the latter do not know how to react and leave it open.

[31]The number of books at home is a frequently used measure of the home environment of children, cf. Kirsch et al. (2002); Storch and Whitehurst (2001).

Table 3: Baseline Results, Fourth Grade, 1999-2005

Dependent Variable:	**Test Score Mathematics**						**Test Score Language**					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mulatto	-0.159**	-0.154**	-0.00691	-0.000268	-7.07e-05	-0.000888	-0.131**	-0.126**	-0.000958	-0.000373	-0.00228	-0.0184
	(0.0151)	(0.0151)	(0.0142)	(0.0143)	(0.0143)	(0.0146)	(0.0146)	(0.0145)	(0.0125)	(0.0128)	(0.0129)	(0.0137)
Black	-0.500**	-0.487**	-0.258**	-0.250**	-0.247**	-0.249**	-0.450**	-0.440**	-0.230**	-0.227**	-0.225**	-0.244**
	(0.0192)	(0.0195)	(0.0197)	(0.0204)	(0.0205)	(0.0223)	(0.0182)	(0.0176)	(0.0157)	(0.0163)	(0.0161)	(0.0187)
Asian	-0.129**	-0.111**	-0.0502	-0.0621*	-0.0566	-0.0546	-0.108**	-0.101**	-0.0361	-0.0405	-0.0315	-0.0239
	(0.0327)	(0.0312)	(0.0291)	(0.0302)	(0.0291)	(0.0333)	(0.0301)	(0.0301)	(0.0285)	(0.0295)	(0.0294)	(0.0325)
Indigenous	-0.179**	-0.181**	-0.0614*	-0.0672*	-0.0677**	-0.0632*	-0.129**	-0.123**	-0.0376	-0.0462	-0.0438	-0.0602*
	(0.0297)	(0.0294)	(0.0262)	(0.0261)	(0.0259)	(0.0285)	(0.0287)	(0.0288)	(0.0273)	(0.0276)	(0.0276)	(0.0298)
Female	-0.0888**	-0.0865**	-0.0719**	-0.0746**	-0.0723**	-0.0726**	0.203**	0.211**	0.229**	0.226**	0.230**	0.228**
	(0.0109)	(0.0110)	(0.0107)	(0.0113)	(0.0114)	(0.0119)	(0.00993)	(0.00993)	(0.00966)	(0.00997)	(0.0100)	(0.0112)
Age	-0.166**	-0.158**	-0.0906**	-0.0925**	-0.0914**	-0.0870**	-0.163**	-0.155**	-0.0907**	-0.0926**	-0.0912**	-0.0955**
	(0.00434)	(0.00422)	(0.00397)	(0.00392)	(0.00393)	(0.00431)	(0.00467)	(0.00443)	(0.00402)	(0.00389)	(0.00391)	(0.00440)
Tap water		**0.342****	**0.149****	**0.145****	**0.122****	**0.132****		**0.361****	**0.169****	**0.167****	**0.134****	**0.114****
		(0.0195)	(0.0169)	(0.0172)	(0.0176)	(0.0200)		(0.0207)	(0.0186)	(0.0194)	(0.0202)	(0.0228)
Electricity					0.266**	0.247**					0.320**	0.297**
					(0.0278)	(0.0306)					(0.0295)	(0.0326)
Wealth						0.0633**						0.0233**
						(0.00944)						(0.00847)
Constant	2.055**	1.665**	0.993**	0.984**	0.742**	0.759**	1.856**	1.442**	0.822**	0.820**	0.530**	0.680**
	(0.0607)	(0.0596)	(0.0533)	(0.0468)	(0.0529)	(0.0577)	(0.0634)	(0.0616)	(0.0520)	(0.0462)	(0.0517)	(0.0579)
Time Dummies	**Yes**	**Yes**	**Yes**	No	No	No	**Yes**	**Yes**	**Yes**	No	No	No
School Dummies	No	No	**Yes**	No	No	No	No	No	**Yes**	No	No	No
School×Year Dummies	No	No	No	**Yes**	**Yes**	**Yes**	No	No	No	**Yes**	**Yes**	**Yes**
Observations	154,756	152,391	152,391	152,391	150,709	125,417	154,529	152,079	152,079	152,079	150,335	124,559
Adjusted R-squared	0.097	0.109	0.345	0.368	0.370	0.374	0.104	0.117	0.321	0.342	0.344	0.343

Notes. Columns 1 to 6 show results for mathematics, columns 7 to 12 for Portuguese. Significance levels: *<0.05, **< 0.01. All specifications are clustered at the school level. The dependent variable and the wealth indicator are standardized.

4.2. Robustness Checks

The coefficient of our variable of interest has been very stable in size and significance so far. In this section, we further scrutinize the assumption that no omitted variables drive this effect. A major concern in addition to those that we have refuted above is that some of the controls and the tap water access are determined by omitted variables that drive these effects but also the dependent variable. This may, for example, be true for the electricity indicator variable. It could be that this variable and the tap water access indicator capture unobserved heterogeneity with respect to the child or to the household of the child that drives both variables and the test scores of the child. The coefficient β_1 would then be biased. One obvious candidate for this heterogeneity is the financial capability of the family to live in areas where both services are available and to afford connection and consumption fees. We control for this by the wealth index discussed above.

Another factor driving the locational choice of the households may be the importance that parents attach to their children and their children's health. It is, for example, possible that parents without access to tap water know about the danger of missing access to piped water and also have the financial means to move, but are not willing to invest into the health of their children by changing location. Similarly, parents who know about the beneficial effect of electricity availability e.g. in order to study in the evening, have to decide whether they invest into school achievements by connecting to the grid or even by moving first to be able to connect.[32] We add several variables to control for this type of omitted variable bias. Panel A in table 5 shows the results. Column 1 repeats our preferred specification. The first variable we add is an indicator about how often parents have lunch or dinner together with their children. It distinguishes between "Never, almost never", "From time to time" and "Always, almost always". The next variable is an simple index, *care*, constructed by adding up the answers to several, probably collinear questions: "How often do your parents verify that you did your homework?", "How often do your parents verify that you leave for school on time?", "How often do your parents ask about what happened in school?", and "How often do your parents remind you to have good grades at school?" The answers are the same as above and we assigned the values 1, 2, and 3 to the answers, respectively.

[32] Access to the two types of infrastructure services is not completely driven by the same transaction costs. Whereas it is relatively easy to illegally connect to the electricity grid by diverting electricity, it is difficult to connect to a water network lying beneath the streets (Feler and Henderson, 2011). The situation again looks different in settlements where water is pumped into water tanks and small tubes then lead to the households. One of the authors discussed with favela inhabitants who reported frequent illegal diversion of water from such water tanks. Households in rural areas often use generators to produce electricity.

Table 4: Baseline + Home Environment, Fourth Grade, 1999-2005

Dependent Variable: Test Score Mathematics, Grade 4					
	(1)	(2)	(3)	(4)	(5)
tap water	0.124**	0.126**	0.119**	0.118**	0.114**
	(0.0202)	(0.0202)	(0.0201)	(0.0202)	(0.0210)
electricity	0.243**	0.246**	0.226**	0.225**	0.215**
	(0.0312)	(0.0319)	(0.0320)	(0.0321)	(0.0339)
wealth	0.0442**	0.0441**	0.0468**	0.0475**	0.0542**
	(0.00955)	(0.00959)	(0.00970)	(0.00970)	(0.0102)
Mum_primary	0.108**	0.0984**	0.0914**	0.0932**	0.0960*
	(0.0292)	(0.0311)	(0.0310)	(0.0312)	(0.0381)
Mum_secondary1	0.191**	0.169**	0.162**	0.165**	0.156**
	(0.0321)	(0.0332)	(0.0327)	(0.0330)	(0.0371)
Mum_secondary2	0.349**	0.312**	0.301**	0.304**	0.292**
	(0.0333)	(0.0359)	(0.0355)	(0.0357)	(0.0408)
Mum_university	0.222**	0.194**	0.186**	0.189**	0.198**
	(0.0335)	(0.0352)	(0.0353)	(0.0356)	(0.0422)
Mum_don't know	0.113**	0.0766*	0.0688*	0.0724*	0.0713
	(0.0296)	(0.0313)	(0.0311)	(0.0314)	(0.0375)
Dad_primary		0.0308	0.0354	0.0377	0.0226
		(0.0294)	(0.0297)	(0.0299)	(0.0341)
Dad_secondary1		0.0412	0.0472	0.0507	0.0424
		(0.0318)	(0.0319)	(0.0320)	(0.0359)
Dad_secondary2		0.109**	0.110**	0.111**	0.101*
		(0.0356)	(0.0359)	(0.0360)	(0.0397)
Dad_university		0.0566	0.0584	0.0611	0.0381
		(0.0325)	(0.0328)	(0.0329)	(0.0370)
Dad_don't know		0.0733*	0.0727*	0.0748*	0.0600
		(0.0286)	(0.0290)	(0.0291)	(0.0329)
child works			-0.186**	-0.187**	-0.199**
			(0.0172)	(0.0173)	(0.0182)
with parent(s)				0.0678**	0.0822**
				(0.0189)	(0.0203)
books					0.0516**
					(0.0158)
Constant	0.545**	0.505**	0.518**	0.446**	0.507**
	(0.0675)	(0.0704)	(0.0698)	(0.0721)	(0.0770)
Observations	121,046	119,008	118,074	117,395	99,532
Adjusted R^2	0.379	0.382	0.386	0.386	0.395

Notes. Significance levels: *<0.05, **< 0.01. All specifications contain school specific time effects and all variables used in column four of table 4. Standard errors are clustered at the school level. The dependent variable and the wealth indicator are standardized.

The higher the index, the more the parents ask or encourage their child to speak about school. The third and fourth variable also measure parents' interest in their child's school results but require more than asking or motivating verbally. In the third column, we add an indicator about how often the parents help their child with homework. In the last column, we add how often they attend parent-teacher conferences. All of these additional variables are different from the variables that we used in the baseline specifications above because they are probably conditional on the schooling achievement of the child. This is exemplified best by the homework variable. It is negatively related to test scores, which may reflect that parents care more about helping their child if the child performs badly at school. The fact that our variable of interest (and also the electricity variable) remain again totally unaffected in size and significance by the additional variables reduces both concerns. Controlling for the above variables one by one or splitting the index into its components does not affect these results.

Panel B of table 5 shows further robustness checks. The first column repeats the results of our preferred specification. Column two and three show the coefficient of the drinking water variable of the same specification run on the rural and the urban school sample separately. As shown in the descriptive statistics, children's characteristics, test results and families are very different in rural and urban areas. Whereas the urban sample shows the same results as the full sample, the rural sample only shows significant results for the baseline variables (being black, age, gender, education of the mother and child works indicator) and the explanatory power of the regression model decreases by ten percentage points. This is an interesting result as the unconditional differences between the families with and the families without access to tap water (table 3) indicated that most of the variation is to be found in the rural sample. One possible explanation could be that families in rural areas have better ways to cope with missing access to piped water whereas in urban areas, safe substitutes are not easily available. The literature shows that health benefits from access to piped water in adequate amounts are larger in urban areas (Margulis et al., 2002). Another explanation could be the uncertainty about the location of the access point and the source of the freshwater. As explained in section 3.1, the SAEB question does not allow to distinguish private in-house access to piped water from shared taps or taps on the plot of families. Additionally, Brazilian census data show for the year 2000 that almost 60 percent of the rural households rely on water from wells or springs even if they have a piped water connection. Stated differently, more than half of the households have access to piped water at home, but the source is not the publicly provided network but some other source on their property, such as a private well or spring. In urban areas, only

Table 5: Robustness Checks, Fourth Grade, 1999 - 2005

Panel A: Does Parents' Attitude Drive the Effect?

	Dependent Variable: Test Score Mathematics, Grade 4				
	(1)	(2)	(3)	(4)	(5)
Tap Water	0.118**	0.109**	0.104**	0.115**	0.145**
	(0.0202)	(0.0209)	(0.0210)	(0.0214)	(0.0239)
Eat togehter		0.110**	0.0918**	0.106**	0.110**
		(0.0108)	(0.0105)	(0.0107)	(0.0120)
Care			0.0268**	0.0436**	0.0389**
			(0.00410)	(0.00420)	(0.00480)
Homework				-0.140**	-0.154**
				(0.0102)	(0.0114)
Attend					0.0370**
					(0.0140)
Constant	0.446**	0.275**	0.0631	0.193*	0.131
	(0.0721)	(0.0857)	(0.0918)	(0.0929)	(0.112)
Observations	117,395	96,361	96,261	94,209	79,743
Adjusted R^2	0.386	0.401	0.403	0.414	0.395

Panel B: Further Robustness Checks

	Dependent Variable: Test Score Mathematics, Grade 4							
	all	**rural**	**urban**	**PC2/3**	**PNAD**	**w/o 2001**	**inter**	**inter w/o 01**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
tap water	0.118**	-0.0116	0.147**	0.116**	0.120**	0.0854**	0.184**	0.1307**
	(0.0202)	(0.0523)	(0.0216)	(0.0203)	(0.0201)	(0.0275)	(0.004)	(0.0007)
electricity	0.225**	0.0964	0.286**	0.219**	0.231**	0.251**		
	(0.0321)	(0.0599)	(0.0360)	(0.0329)	(0.0311)	(0.0345)		
wealth	0.0475**	0.0251	0.0492**	0.0504**	0.0489**			
	(0.00970)	(0.0318)	(0.0100)	(0.00973)	(0.0111)			
2nd PC				-0.0653**				
				(0.00645)				
3rd PC				-0.000888				
				(0.00714)				
wealth PNAD					0.0584**			
					(0.00850)			
Observations	117,395	8,630	108,765	117,395	121,989	82,174	118,941	82.998
Adjusted R^2	0.386	0.271	0.375	0.390	0.389	0.385	0.367	0.370

Notes. Significance levels: *<0.05, **< 0.01. All specifications contain school specific time effects and all variables used in column four of table 4. Standard errors are clustered at the school level. The dependent variable and the wealth indicator are standardized.

7 percent of the households in 2000 relied on water from own wells or springs. Fresh water thus comes from the chlorinated central water supply for the majority of urban households with piped water access. Whereas the water quality in rural areas may be inappropriate by international standards, pollution pressure on surface and ground waters in urban areas is extremely high in Brazil as only 10 percent of sewage collection in urban areas were treated in 2000 (PNSB, 2000). The Brazilian Ministry of the Environment reports from river and groundwater monitoring that the pathogen load from sewage is bad or even extremely bad close to and in metropolitan or highly urbanized areas (MMA, 2006). This means that our results from urban areas can capture a quality difference between piped and non-piped water access in urban areas, which is not present to the same amount in rural areas. It would be interesting to take a closer look at these differences to see whether differences in water quality or location and type of access point drive the difference in results between the two samples, but our data do not allow this.

We have argued above that we control for the differences in wealth of the children's families by using the first component from a principal component analysis with a large set of indicator variables about household size and equipment. While the first component captures the largest amount of variation in these variables, the second and third component explain other dimensions of the variation in wealth. We therefore complement the first principle component of the long term wealth index with the second and third component in column 5. The coefficient of interest, the effect of tap water, is not affected by this change. In column 6, we use a different wealth indicator instead of the principal components in order to foreclose the possibility that our results are sensitive to the choice of wealth indicator. We construct the second wealth indicator, *Wealth PNAD*, from the 2004 wave of the national Brazilian household survey, PNAD. These data contain monthly per capita income in addition to the variables that we use for the principal component analysis with the SAEB data. However, PNAD is only representative at the level of the 27 Brazilian states. In order to obtain an income proxy from the PNAD data, we therefore regress average monthly income per capita on the indicator variables that we also use for the principal component analysis and then predict income with the SAEB indicator variables for each household separately using the resulting coefficients. We obtain the coefficients separately for each state. Appendix A.1 shows the fit of the imputation for the first three states. The correlation between the imputed income variable in SAEB using the PNAD coefficients and the first principal component is 0.85. The correlation between "true" income per capita and the predicted income (both values from PNAD data) is 0.58. This underlines our hypothesis that we do not exactly proxy income but the long term wealth component reflected also in monthly wages. Column 6 shows that replacing the first principal component by the imputed values does not alter our results.

Column 4 shows the results from the baseline specification run on a sample not including the 2001 wave. We exclude 2001 because of concerns about data quality. From the 2001 to the 2003 wave, the sampling changed and took into account many more areas for rural sampling in 2003 and 2005. In 1999 and 2001, rural schools were tested and interviewed only in the federal states of Minais Gerais and Matto Grosso do Sul, and in the federal states of the North-East region. From 2003 on schools in rural areas of all states were included into the sample. It is a priori unclear whether the inclusion of these areas increased the average availability of public water infrastructure in the sample. The newly added regions are not known to be served better (or worse) with infrastructure on average. The North, for example, is known to be the least equipped with public infrastructure, the states of Rio de Janeiro or Sao Paulo are the most developed states in Brazil and have been so for a long time. Excluding the 2001 observation reduces the coefficient significantly but it remains significant at the one percentage level.

As a last robustness check we add a large number of interaction terms to the specification in column 1. This addresses the concern that the linear form chosen to estimate the effect of access to tap water on test scores may not be flexible enough to account for all differences between the group of children with access to tap water and the group of children without tap water. The specification that we estimate here comes close to a fully saturated model allowing for more functional flexibility.[33] As we are concerned about the robustness of our results at this point, we do not report the coefficients of the interaction terms. We report the average partial effects of tap water for the sample with and without the 2001 observations (columns 7 and 8). The average partial effect is calculated as the average of all predicted values from the specification with all interactions. It is thus the overall effect of having access to tap water on test scores.[34] The average partial effect is 18 percent if we use the full sample and reduces to 13 percent if we drop the observations from 2001.

[33]The specifications include interaction effects between ethnic background and tap water, sex and tap water, sex and education of the mother, age and education of the mother, age and tap water, electricity and education of the mother, electricity and income, tap water and income, child works and education of the mother, tap water and child works, tap water and education of the mother, tap water and electricity and all of the respective main effects.

[34]The average partial effect is conceptually close to the partial effect evaluated at the mean of all variables included in the interactions. However, it uses the predicted values for each observation instead of the average value of the variables. This accounts for the fact that most variables in our specification are binary and therefore cannot take mean values. Note that we additionally demeaned the income and the age variable in order to make the average effects comparable to the OLS results.

Both effects are significant at the one percentage level.

5. Effect Heterogeneity

In order to design policy measures that improve the lives of the poor in a cost effective way, it is important to know which group of the population can benefit most from a given policy program. While we have argued above that access to piped water only affects children in urban environments, we now further investigate effect heterogeneity with respect to the educational level of the mother and family income. Two studies have addressed differential effects from access to tap water on health so far. They both report important complementarities between access to tap water and the education of the mother of a child (Gamper-Rabindran et al., 2010; Jalan and Ravallion, 2003). There are two potential effects of higher education of the mother. First, an educated mother probably knows better how to treat water to render it safe. Second, hygiene is expected to be better with an educated mother as she probably trains her children better to follow basic hygienic rules. Her children do not contract water-related diseases as often as children of non educated mothers. With respect to the interaction of access to clean water and the household income, the two studies find different effects. On one hand, Jalan and Ravallion (2003) find with an individual level data set from India that only children from households with incomes above extreme poverty benefit from access to tap water in terms of less diarrhea incidence and shorter duration of diarrhea. The authors suggest that resources and capabilities of uneducated and extremely poor families are too low to make their children benefit from access to tap water. On the other hand, Gamper-Rabindran et al. (2010) find that Brazilian municipalities at lower development stages experience larger reductions in infant mortality when access to tap water increases than municipalities at higher levels of development. They suggest a substitution effect of income and water access at higher development levels.

While the above literature focuses on the effects of access to piped water on health outcomes of children, we are interested in the effects on school attainment as measured by test scores. We therefore interact the dummy variable for tap water with the different educational levels of the mother and with income. We focus on the urban sample as we found no effects in the rural sample and aggregate educational levels from the 9th grade on as we do not expect results to differ at higher levels (cf. table 4). Table 6 shows the results for the interaction with education. The interactions of tap water and educational levels with (standardized) income are not significant (not shown). Several conclusions emerge from the results. First, the effect of tap water without education at the mean income is insignificant. Second, also higher income does not cause a positive effect of access to tap water. This means that the average effect that we found above is driven by the positive significance of the effect for children with educated mothers. The effect of drinking water is strongest for mothers with basic secondary education. Children from all families, regardless the wealth level, benefit from access to tap water if the mother disposes of more than primary education.

Table 6: Effect Heterogeneity, Urban Sample,
Fourth Grade, 1999-2005

Dependent Variable: Test Score Math, Grade 4	
Tap water	0.0627
	(0.0917)
Mum_primary	0.0770
	(0.0911)
Mum_secondary1	0.0417
	(0.0909)
Mum_Higher	0.196**
	(0.0881)
Mum_don't know	0.116
	(0.0845)
Mum_primary*Tap water	0.127
	(0.104)
Mum_secondary1*Tap water	0.241**
	(0.0993)
Mum_Higher*Tap water	0.166*
	(0.0994)
Mum_don't know*Tap water	0.0939
	(0.0961)
Observations	93,295
Adjusted R-squared	0.379

Notes. Note: Significance levels: *<0.1, **<0.05, ***< 0.01. All specifications contain school specific time effects, all control variables from previous regression, and standard errors are clustered at the school level.

Our results accord with the evidence found by Jalan and Ravallion (2003) for effects conditional on the educational background of the mother, but we do not find that this increase is conditional on wealth levels. This may reflect the fact that we are interested in the effects of access to tap water on human capital formation and not on health. It may be that long term family input such as the education of the mother is more important for human capital formation than the short-term effects of medicine that can be bought with higher income.

6. Conclusion

We analyze the effect of access to piped drinking water at home on educational achievements of fourth graders in Brazilian primary schools. We find that there is a positive and significant effect, which explains around 14 percent of the standard deviation of average test scores in urban Brazil. We find that this effect is conditional on the education of the mother but not on income. We identify these effects relying on school-specific time effects and by conditioning on a large vector of child and family characteristics. The fact that the coefficient estimate of access to tap water at home is extremely stable once we control for location and time-specific heterogeneity as well as for indicators of the socioeconomic background of the children confirms our identification strategy.

Based on recent literature about the development of cognitive development and the decisive role of health in early childhood for human capital development, we suggest that our estimate depicts the positive effect of a better health environment in early childhood on human capital formation in the form of access to piped water. Piped water access, in combination with appropriate sanitation access, has been shown to sharply reduce the incidence of water-related diseases which mostly affect young children and have strong effects on their health. To the best of our knowledge, we are the first to provide evidence for a link between piped water access and educational achievement as measured by test scores from standardized school exams.

Our results suggest that investment into large scale drinking water infrastructure should be complemented by educational campaigns especially for educationally disadvantaged families. According to our results, tap water access does not translate per se into substantial improvements of educational achievement since children of mothers without more than basic education but with access to tap water perform similar to children without access to tap water. As the conditionality of positive effects of access to piped water on education of the mother has already been shown for water-related health outcomes, this outcome further substantiates policy recommendations that call for a larger weight on hygiene education in development programs.

With respect to the external validity of our results, the finding that only children in urban areas benefit from access to tap water in terms of human capital formation needs to be put into the context of the study area. Spears and Lamba (2013), for example, find with data from rural India that the improvement of the early-childhood health environment by putting into place more pit latrines increases the cognitive capabilities of young children substantially. On the one hand, our results for children in rural schools may thus be specific to Brazil or conditional on the sanitation situation in rural Brazil that we could not study with the data at hand. On the other hand, other research shows that improving water quality in rural areas in Kenya by community spring protection does not bring about improved health for children aged below five years (Kremer et al., 2011). Kremer and Zwane (2007) also discuss evidence documenting that any type of community-level water access short of pipes to the households does not yield significant gains in terms of water-related health. Against this background, our results are very interesting and further research focusing on the rural context is needed.

A. Appendix

A.1. Principal Component Analysis

Table A.1: Components and Eigenvalues

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	3.59472	2.20865	0.2996	0.2996
Comp2	1.38608	.100524	0.1155	0.4151
Comp3	1.28555	.440647	0.1071	0.5222
Comp4	.844905	.0410657	0.0704	0.5926
Comp5	.803839	.100665	0.0670	0.6596
Comp6	.703175	.0343893	0.0586	0.7182
Comp7	.668785	.0484794	0.0557	0.7739
Comp8	.620306	.0360971	0.0517	0.8256
Comp9	.584209	.0350637	0.0487	0.8743
Comp10	.549145	.0146059	0.0458	0.9201
Comp11	.534539	.109791	0.0445	0.9646
Comp12	.424749	.	0.0354	1.0000

Note: This table gives the eigenvalues from the principal component analysis with the variables given in the next table. Nobs: 267.255; PCA unrotated

Table A.2: Eigenvectors of the first 3 components

Eigenvectors			
Variable	Comp1	Comp2	Comp3
Household size	-0.1572	0.6981	0.1615
Domestic help	0.2332	0.1639	-0.3008
Rooms p.c.	0.2338	-0.6045	-0.2170
# of Cars	0.3469	0.1609	-0.1965
TV	0.2226	-0.0714	0.5497
Radio	0.2682	0.0898	0.0500
PC	0.3475	0.1651	-0.2667
Fridge	0.2576	-0.1009	0.5494
Vacuum cleaner	0.3323	0.1551	
Video	0.3525	0.0940	0.0119
Freezer	0.3152	0.1051	0.0406
Cloth washer	0.3214	-0.0010	0.2656

Note: This table gives the eigenvectors for the first three components of the PCA above.

A.2. Income Imputation from PNAD, 2004

The figures show the cumulated density function of the true monthly income (blue line) and the imputed monthly income (red line). The spikes are due to the fact that we impute with indicator variables whereas income is a continuous variable. The imputed variable from the asset indicator variables overestimates income, which is a common result.

Figure A.1: Rondônia

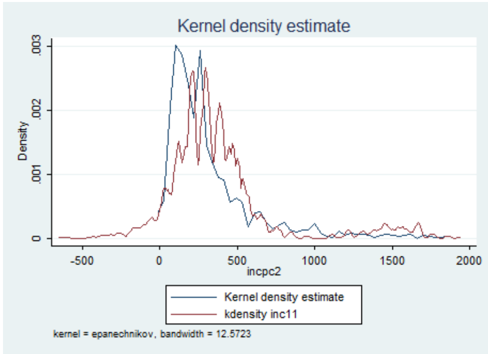


Figure A.2: Acre

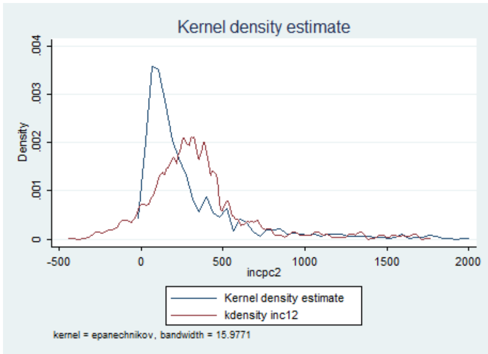
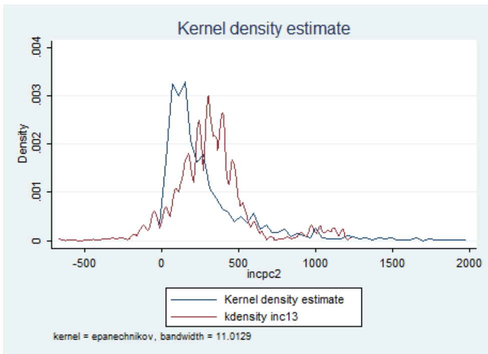


Figure A.3: Amazonas



We only plotted the estimates and imputed values up to a monthly per capita income of 2,000 Reals (1,092 US-Dollars) to give the overall idea of the distribution. Four percent of the sample in PNAD have per capita incomes above 2,000 Reals per month.

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