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Impact of access to water and sanitation services on educational attainment

by

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Impact of access to water and sanitation services on educational attainment

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Abstract

Without proper water and sanitation services, children are prone to the contagion of waterborne diseases. When not sick, children and their caregivers have to allocate their leisure time in order to meet their water and sanitation needs. It is through these health and leisure time use changes that access to water and sanitation services impacts the educational attainment of children. To explore the impacts, this paper proposes a household utility maximization model in which access and sanitation services are determinants of the child's health. In turn, education depends on the health status of the child. Comparative statistics indicate that households consider the health gains to the market value of their leisure time, and the changes in the consumption of other goods. In order to sort out the endogeneity between provision of access to water and sanitation services, and educational attainment, this paper uses an instrumental approach based on the technical features of the water systems and, as a novelty, the number of rivers within the municipality territory. Estimates suggest that access to water and sanitation services has a positive and significant effect on schooling, when measured by the completed number of school years. These positive effects call for the expansion of the laggard sewerage systems in the country, both at home and at school, by using different technologies.

Keywords: water, sanitation services, education, Brazil.

JEL classification: Q25, I24, I38.

I. Introduction

Water is needed for human life and health, as well as for agricultural and industrial production. All these uses may lead to pressures on water resources and can cause or aggravate problems of scarcity and inequality. Brazil is a country marred by inequalities (Herran 2005). In terms of water, the very water-abundant northern region borders the semi-desert northeastern region. As for access to water and sanitation services, the economically prosperous southeastern and southern regions, as it will be seen, fare better in the provision of access to water and sanitation services than the poorer regions of the country. Nevertheless, the growth of the urban areas in the rich southeast and south pose a serious risk for water availability and rational use.

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Inequality in access to water and sanitation may translate into human capital inequalities, specifically, in health and education. When not connected to the water and sewerage system, household members, in particular children, can be more prone to the contagion of water-related and water-transmitted diseases that prevent them from attending school and from academically succeeding. Children may end up spending more time in collecting, hauling, and taking care of water storage than in attending school or doing homework. This change in time use can be even more deleterious for women, as it prevents them from engaging in economic activities. Without proper water and sanitation services, proper hygiene is not maintained, which, in turn, increases the likelihood of contracting diseases. It is the goal of this paper to estimate the impact of access to water and sanitation services on school attainment in Brazil, by using data from the 2010 national census, and an experimental variable econometric technique to be explained later.

Academic performance depends on access to water and sanitation services in two different ways. First, water-related diseases are transmitted through five main routes: waterborne diseases (like cholera and typhoid), water-washed diseases (for instance, trachoma), water-based diseases (such as schistosomiasis), water-related and vector-borne diseases (such as malaria, filariasis, and dengue), and water-dispersed infections (such as legionellosis) (Hutton 2012). With better water, sanitation services and, consequently, better hygiene, households would experience savings in health-care expenditures, and productive time loss, and would avoid the costs of premature death of family members. Second, and although not replicated in children, studies have found that adults suffering from dehydration experience harmed discrimination, psychomotor, and short-term memory (Kaushik et al. 2007). Similar outcomes are, arguably, expected in children suffering from dehydration. As a consequence, lack of water impairs children's academic performance by reducing their cognitive capacity. If not fully dropping out of school due to disease, insufficient provision of water and sanitation can still affect learning capacity.

The goal of this paper is to explore how access to water and sanitation services leads to differences in school attainment, measured by the completed school years [1]. For Brazil, the study of access to water and sanitation services is relevant, mainly because of the inequalities across the country. Poor semi-desert regions may be condemned to a vicious cycle of poverty, because water scarcity translates into reduced schooling and lower human capital accumulation. Another reason is related to the institutional and technical conditions of the water and sanitation sector in the country. Water shortages and badly functioning water and sewerage systems can curtail the effectiveness of education and health spending of all levels of government. The final point of relevance comes from an international and sustainability perspective. Impacts from global warming on water availability will force policymakers and users to consider better ways to deliver the services, and to make rational use in a fashion that is sustainable and that may not pose risks to human health.

This paper can be situated in the strand of literature that studies the determinants of school attainment and performance in developing countries. However, it can also be placed in the strand of literature that studies the impact of access to natural resources. Human use of water is made within a hydrological system and, therefore, its consumption has implications about sustainability and efficiency. From the perspective of development economics, this paper deals with the effects of health and income earning activities on household welfare. Also, and due to the nature of water and sanitation services (public services highly regulated by government authorities), this paper can be placed in the literature that explores the impacts of government programs.

As its first contribution, this paper explores how access to natural resources becomes a barrier to social policy in a developing country. In the case of Brazil, it is possible that conditional-cash transfer programs can actually have a bigger impact in breaking the path of poverty if water and sanitation are also available for households. Expanded coverage will result in healthier households and more time available to achieve higher levels of education. It is entirely possible that social policy will have to be integrated within a wider framework of environmental policy, river basin management, and delivery of services in order to achieve higher welfare levels.

Tackling endogeneity and simultaneity in the study of access to water and educational achievement is the second contribution. Endogeneity has been acknowledged in previous studies, but, in the case of Brazil, has not been directly addressed. It is important to solve the endogeneity problem because, otherwise, all estimates can be biased and lead to the wrong policy implications. The final contribution is to propose a household utility maximization model relating access to water and sanitation services to education. In the model, households make decisions on consumption of goods, education, and time. Education is a function of the health of children and, in turn, their health depends, among other things, on the level of access to water and sanitation services. The comparative statistics suggest that household compares the health and education gains of their children to the market value of the leisure time and to the changes in the consumption of other goods. Based on this model, some hypothesis will be derived and will be empirically tested.

Results to be presented indicate that there is a positive effect of access to water and sanitation services on the number of completed school years in the 2010 Census sample. The impact of the access to sanitation services (measured through having a connection to the sewerage system) seems to be larger than the connection to a piped water source. By using different samples defined by the age of children, it seems that the effect builds up over time: the longer the children are exposed to the connection to sewerage and water systems, the wider the difference in school years with respect to those that do not enjoy such amenities. This time path points at the accumulated effect of health on education. The use of a set of instrumental variables related to water availability and technical specifications of the water systems reveals the real extent of the endogeneity bias.

II. Literature review

We start by identifying the benefits associated with access to water and sanitation services for economic development, and for society as a whole. To do so, access has to be related to the investment on infrastructure. More generally, the main benefits are associated with better health, at the individual and community levels, and with changes in time use at the household level, especially by the mother of the household. As our paper uses Brazil as an example, the institutional background of the water and sanitation services is needed, as well as recent studies exploring how water and sanitation infrastructure impacts health. As the output variable is the schooling, measured as the number of completed school years, some findings of previous studies explaining school enrollment are discussed, as well.

a) The benefits of access to water and sanitation services

Access to water and sanitation services was defined as a human right by the United Nations (Dublin Conference declaration 1992). The human rights perspective obliges governments to act in a positive and proactive way, for instance, by expanding coverage, since water is a guarantee for an adequate standard of living (Anand 2007). Moreover, the human right to water is related to the millennium development goals of reducing hunger and child mortality, as well as improving maternal health, gender equality, and primary education enrollment.

Improving access to water and sanitation services will represent economic gains to societies all over the world. In a report published by the World Health Organization (WHO) (Hutton 2012), the global economic return on sanitation services is found to be US$ 5.5 per US dollar invested, while the return on water supply is US$ 2.0 per US dollar invested. The combined intervention on water supply and sanitation services has a benefit-cost ratio of 4.3 at the global level. Inadequate water supply and sanitation services result in economic losses estimated around US$ 260 billion annually worldwide.

The benefits of expanded access will accrue from time savings (around 70% of the benefits), and health care savings (around 10% of benefits). Other benefits are the reduced levels of deaths from diarrhea disease, productive time losses, and premature mortality.

The gains assigned to time savings cannot be taken simply. In an example of an economic assessment of water interventions (Cameron and Jagals 2012), the authors argued that better water supply reduces the number of sick days associated with water-related illnesses (six days per person, per year). As the incidence of diarrhea falls, the time available for livelihood activities increases (three days per person, per year, per episode). Healthy individuals would spend less time caring for the sick (half a day per day of illness). The rule of thumb to assess the success of a water intervention, taking into account the savings in treatment costs by households and the public sector, is a benefits-cost ratio greater than 1.5.

The expansion of access to water and sanitation services has to be understood in the larger framework of infrastructure provision. The benefits of better water and sanitation services accrue mainly to households through a higher welfare by disease prevention. There are three main challenges in improving the access and quality of water and sanitation services: first, the significant investments on operation and maintenance; second, lack of governance policies, promoting private sector involvement; and, third, difficulties in setting appropriate pricing structures. Even though the returns on infrastructure tend to fall as economies develop, this is not, yet, the case for Latin American countries' investments in water and sanitation services infrastructure (Briceño-Garmendia et al. 2004).

Inequality in access, level of household expenditure on water, and the water quality are the main drivers of the expected high return on the water and sanitation investments throughout Latin America. Overall, rural populations have a lower access to drinking water. Poor areas, either urban (slums) or rural, face a reduced supply of drinking water due to unrecoverable investment costs and low levels of operation and maintenance. Water expenditure inequality refers to the fact that, usually, the higher the expenditure, the higher the scarcity. For instance, poor urban and rural Brazilians spend almost two times more on water than wealthier Brazilians. As for the water quality inequality, 60% of the population is connected to hydraulic water systems that do not run constantly and supply poorly treated water (Rangel et al. 2002).

Construction of water and sanitation systems is followed by water connection decisions made by families. Subsidies have tended to target consumption and not the connection costs (Bajpai and Bhandari 2001). Poor households might be unable to afford the upfront costs of connection. An increasing block tariff system (IBT) can result in several poor households sharing a connection and paying more than individual users. In a randomized controlled trial in urban Morocco, Devoto et al. (2011) found that access to credit, and not the costs, is the real obstacle to improve households' access to higher-quality water. With better information about credit programs, households are willing to make the lump-sum investment on water that improves their welfare.

b) The effects of access to water on health

Water diseases are classified in five groups: a) diseases caused by lack of water and poor hygiene; b) diseases caused by direct contact with polluted water; c) diseases transmitted by water born vectors; d) diseases disseminated by water ways and e) diseases transmitted by water (Razzolini and Günther, 2008).

Governments invest in water and sanitation services infrastructure, aiming at achieving full coverage, mainly because of the effects on health. There are five channels through which better health improves the wealth and economic performance of a society (Bloom et al. 2005). First, healthier children perform better in school. Second, healthy adults are more productive at work and can take better care of their offspring. Third, health improves the capital base of the society, because people have to save more for retirement. Fourth, healthy societies have more dynamic economies, because the ratio of workers to dependents increases. Finally, healthier societies attract more investment and tourism.

The hygiene improvements resulting from access to potable water and improved sanitary services have been key in reducing the morbidity and mortality from infections transmitted by fecal-oral or other direct contact routes. Better hygiene and safer excreta disposal have a bigger impact on health than improved drinking water alone (Aiello and Larson 2002). There are three key hygiene attitudes related to water and sanitation that can reduce the burden of infections: hand washing with soap (or ash), the safe disposal of feces, and the proper storage and handling of water. Nevertheless, the way hygiene improves health is not free of debate. For instance, the desire to feel and smell clean and to follow social norms may be more effective in changing hygienic behaviors than health considerations (Fewtrell et al. 2005). Following this same strand, an increase in water supply improves health by reducing the need for storage and transport activities with a high likelihood of polluting water. When water systems do not work constantly, water quality interventions have to take place at the point of consumption rather than through construction of water systems.

One of the variables that is most impacted by better access to water and sanitation services is child mortality. For urban areas, access to potable water and sewerage connections does reduce child mortality (Shi 2006). Even though the effects can be offset by urban growth and poverty levels, greater local government intervention and private or parastatal participation in water and sanitation provision also reduce child mortality. If not mortality, water is related to high levels of morbidity due to the incidence of diarrhea and severe diarrhea. A severe case of diarrhea is defined by three or more watery or loose stools during a 24 hour period (WHO 2004).

c) The mechanisms of time use and mothers' outcomes

Households may have more time available to engage in income-generating activities with an enhanced access to water and sanitation services (Rakodi 1999). Households' labor decisions are constrained by the levels of education and skills, health status, and housekeeping activities, such as collecting water and fuel. Health status becomes critical, depending on the household's dependency ratio and its stage over the life cycle. Better access to water not only increases the productivity of households' labor through health gains, it also results in reduced communicable diseases within communities.

Time availability for income-generating activities and education has a clear and strong gender bias (Roy and Crow 2004). In many societies, women and girls carry out the housekeeping and water collection, transportation, storage, and handling. In addition, water rights are usually vested in men, who produce an unequal distribution of water resources. The gender bias acts in two ways: first, women do not have decision power over access for agricultural and productive uses; second, women may suffer from water-borne diseases that prevent them from attending school and from working.

Breaking the cycle of poverty for women, through access to water, may end up in better outcomes for their children. Women's work raises financial independence and their bargaining power within the household, which results in improved child welfare (Koolwal and van de Walle 2010). Nevertheless, increased women's labor participation may have ambiguous effects on children. On one hand, it reduces the care children receive at home; on the other hand, more income makes health and schooling more affordable. Other substitution effects can take place. For instance, mothers' work may lead teenage girls to not attend school in order to take care of the household chores.

When water is not available within the household premises, the distance to the water source becomes a critical variable (Pickering and Davis 2012). Women and children, having the responsibility of collecting water, bear the full cost of fetching the water, both in terms of lost time and physical burden. A shorter distance to the water source is associated with lower incidence of diarrhea, fever and cough, lower child mortality, and better height and weight for age scores.

d) Institutional framework of access to water and sanitation in Brazil

There are five clearly differentiated periods in the institutional history of the provision of water and sanitation services in Brazil (Galvão Junior 2009). In the first period (sixteenth century to mid-nineteenth century), the first institutions of public health and sanitation were created. In the second period (1850-1910), states were given the responsibility of supplying health services, and the provision of water and sanitation was transferred to private utility companies. In the third period (1910-1950), the growth of cities after the end of slavery forced all government levels to set up institutions in charge of water and sanitation services management. In the fourth period (1950-1969), independent municipal utility companies were created, and the sanitation services were linked to health policies. In the fifth and last period (1970 and onwards), the state utility companies were established because the Sanitation National Plan (in Portuguese, PLANASA) entitled municipalities with the responsibility of providing the services, but they, in turn, transferred it to the states

Recent figures indicate that the access to water and sanitation is intertwined with some well-known income and educational inequalities at the regional level (Reymao and Saber 2009). Access in urban areas in the northeast is only 14.7%, which is worse than the 37% access of the northern region. In 2005, only 67.1% of the first income quintile had access to a water system, while the figure skyrockets to 98.5% for the richest quintile. As for education, the percentage of households connected to the water system goes up with the literacy of the head of the household.

The lack of a well-functioning institutional framework is paramount. Setting up the regulatory framework for sanitation services, in particular, is a challenge given the characteristics of the sector itself (da Motta and Moreira 2006). This sector exhibits natural monopolies, due to economies of scale and scope, long maturity investments with large initial costs, low technological dynamism, different degrees of technology adoption, and movement toward the productive frontier. Without proper efficiency incentives, sanitation operators dissipate the productivity potential and charge higher tariffs.

Despite this legal void about the ownership of the services, increased access to public services, such as water and sanitation, has been part of the decentralization agenda. Differences in access to public services at the local level, theoretically, arise from local differences in the valuation and in the provision costs of the services. Decentralization allows for a better targeting of policy interventions, and for local communities to choose the best way to achieve their goals (Ihsan Ajwad and Wodon 2002). Application of a decentralization process in Latin America has been strongly pro-poor in granting access to basic infrastructure, such as water and sanitation, only after the non-poor have achieved higher access levels.

The National Water Agency (ANA, in Portuguese) estimates that the total capacity of water systems is around 587 m3/s, and the maximum current demand is around 543 m3/s. By 2015, it is expected that 55% of the municipalities will experience some sort of water supply shortages. The largest share of those municipalities will require investments to update their water systems, while the remaining ones will need to find and use new water sources. In total, it is calculated that the investments on the water systems and the use of new water sources will amount to US$11 billion up to 2025, 74% of which will have to be invested in the southeast (the region with the largest number of cities) and the northeast (a semi-arid region). In addition, US$22 billion will need to be invested in the sanitary systems of the municipalities with water quality problems (Agencia Nacional de Agua 2011).

e) Impacts of water and sanitation services' expansion in Brazil

Water-borne and water-related diseases continue to be one of the leading causes of morbidity and mortality, especially child and infant mortality, in the world (Fontana et al. 2004). Brazil has seen infant and child mortality rate reductions over the last decade. From an infant mortality rate of 31.9 dead children (per 1,000 live births) in 1997, the rate went to 13 dead children (per 1,000 live births) in 2012 (Figure 1). The Brazilian rate is actually lower than the average rate of the higher-middle income countries – 16 dead children (per 1,000 live births) – by using the World Bank Income Classification (WHO 2014). More importantly, Brazil as a country has closed the gap between child and infant mortality. The difference between child and infant mortality rates is only around two dead children (per 1,000 live births) (World Bank Development Indicators 2014).

The reduction in the infant mortality rate at the municipal level, between 1980 and 2000, was mainly explained by growth in income, reduced illiteracy in women, and adolescent fertility rates, as well as more private health care and basic public services (Barufi et al. 2012). Furthermore, there is evidence of regional spillover effects, even at a higher scale than the local effects of the same variables that explains the reduction in infant mortality.

Government programs contributed to reduce the burden of child and infant mortality throughout the country. The expansion of the Family Health Program (Macinko et al. 2006), which provided primary care services for areas composed of a maximum of 4,500 inhabitants, was related to a reduction in the child mortality rate (a 10% increase in the coverage program is associated with a 4.6% reduction in infant mortality). Nevertheless and at a lower magnitude, improving access to water leads to a 3% reduction in infant mortality. It may seem that government health programs have to be accompanied by an expansion of access to water and sanitation services.

The Brazilian expansion of access to water and sanitation services has been uneven when comparing water to sanitation in urban and rural areas. While access to water in urban areas is around 90% (See Figure 2 and Figure 3), access to sanitation services (connection to sewerage system) in urban areas is only 60%. The situation is grim for rural areas, where only 30% of the population is connected to piped water systems, and only 10% is connected to sewerage systems. Despite this uneven expansion, the percentage of child mortality caused by diarrhea has dropped drastically from 11% in 1991 to nearly 2% in 2009 (IBGE 2014, Figure 4). During the 1993-2010 period, the hospital admissions (per 100,000 inhabitants) due to fecal-oral transmitted diseases diminished from 681.1 to 264.3. Along the same lines, hygiene-related diseases came down from 3.7 to 1.5 hospital admissions. Finally, hospital admissions caused by hygiene-related diseases are only 5.1 (IBGE 2014, see Figure 5 and Figure 6).

In Brazil, it is estimated that low-quality water and poor sanitation services are responsible for 85 of 102 listed illnesses, 24% of total reported sick people, 23% of the total death events from illnesses, and 90% of the diarrhea-caused deaths. Additionally, 3.4 million hospital admissions from 1995 to 2005 were the result of deficient access to water and sanitation services. Improved access could have prevented 80% of the cases of typhoid and para-typhoid fever, around 60% of the cases of trachoma, and nearly 40% of the diarrhea-related diseases. (Razzolini and Günther 2008).

A reduction in the number of diarrhea cases in the country was due to the introduction of rotavirus vaccines into the national immunization program (Ikeda do Carmo et al. 2011). After introducing the vaccine in 2006, the diarrhea-associated mortality was 22% lower from 2007 to 2009 (when compared to the pre-vaccine period). Furthermore, diarrhea-caused admission rates were 25% lower for children under 1 year of age, and 21% for children between 1 year and 2 years of age.

The city of Salvador has undergone an expansion of piped water, drainage, and sewerage systems since the late 1990s. In a study of diarrhea incidence in the city (Moraes et al. 2003), researchers exploited the differences among the group resulting from the introduction of a sanitation program. Researchers found that the incidence of diarrhea was lower in the groups with access to both sewerage and drainage. As for the sanitation technology adoption (Santos et al. 2011), results indicate that flush toilets were the preferred sanitation technology by all age, income, and education level groups. More importantly, this choice is preferred when the number of children in the household increases. Another study followed a group of children before and after the expansion of a sanitation program in the city of Salvador (Barreto et al. 2007). Its results suggest that the sanitation expansion reduced the prevalence of diarrhea by 21% (9.2 days of diarrhea per child, per year to 7.3 days per child, per year). Furthermore, it argues that a higher neighborhood-level coverage, rather than an indoor toilet connected to the sewerage system, curtailing the fecal pollution of the surroundings, leads to a drop in the incidence of diarrhea.

The impact of piped water on infant mortality in Brazil is mediated by two critical factors: first, non-random placement as water systems are usually built in regions with higher health inputs; and second, infant mortality rates are low due to underreporting (Gamper-Rabindran et. al. 2010). It also seems that there exists a threshold of socioeconomic development that changes the effects of access to piped water. Below that threshold, water provision alone does not improve the health of individuals because of low levels of disease resistance, nutrition, and personal hygiene. Results from a quartile regression, on the quartiles of the conditional distribution of the infant mortality rate, indicate that a 1% point increase in the number of households connected to piped water (in municipalities with poor development indicators) leads to a reduction of 1.25 deaths per 1,000 live births at the 90th percentile of the conditional infant mortality rate. The reduction is only of 0.54 deaths per 1,000 live births at the 10th percentile.

Although the endogeneity between health and sanitation was overlooked, results from a fixed effect model found that better access to water and sanitation reduced infant mortality rates (Cardoso de Mendonça and Seroa da Motta 2007). Furthermore, more educated mothers and higher health expenditures also reduced the mortality rate. Interestingly, increasing the coverage of sanitation services reduced mortality by 216 deaths, compared to 108 deaths after increasing access to water. The study argues that expanding access to water and sanitation services would be more costly than an increase in the literacy of mothers or an increase in health expenditure.

f) Enrollment determinants in Brazil

Health gains have come with improvements in education throughout Brazil. Looking at the enrollment rates by age groups (IBGE 2014, Figure 7), the Brazilian education system has made real progress in enrolling all children, up to the age of 14 years, in school. In particular, the country is making great efforts in the early enrollment to education. Dropping out of school is a serious problem for children 15 and older. It seems that government policies cannot properly help children, who are exposed to social, economic, and family factors that force them out of school. Education figures also show that educational achievement is improving (IBGE 2014, Figure 8). The percentage of people completing 11 or more years of school has been growing steadily since 2000, and it is now around 35%. Lower educational levels, overall, are reduced in the 10 years and older population.

Early parenthood, child labor, and poverty may explain school dropout in Brazil. Using a survey conducted in the city of Fortaleza (Cardoso and Verner 2006), answers to questions about ideal age to start having sexual relationships and desired minimum monthly salary were used as instruments to avoid endogeneity between poverty, child labor, and schooling. Instruments are needed because those who dropped-out are not a random sample, and there might be omitted variables explaining the decisions of working, early parenthood, and dropping out of school. The results of the instrumental probit models used showed that early parenthood and extreme poverty increase the probability of dropping out of school by 0.46% and 0.11%, respectively. On the contrary, child labor has no effect on school attendance.

Household income is a key determinant of school enrollment and child labor. The effects of income transfers to households are mediated by the sensitivity of children outcomes. If children outcomes are insensitive, income transfers do not have any effect on human capital accumulation. Brazil underwent a reform in rural workers' social security. In exploring the impact of this reform on child labor participation and school enrollment, for children ages between 10 and 14 (Carvalho Filho 2008), it was found that the effects depend on the gender of the benefits receiver. Male children residing with a male benefit receiver have a lower labor participation rate and a higher enrollment rate. The effect on male children is higher than the effect on the female children. The opposite is true when the benefit receiver is a female. Female children have a low labor participation and a higher school enrollment.

The trade-off between schooling and labor might also be a consequence of the strategy used to smooth consumption when facing a short-term economic shock. Using a panel data to control for the male head of the household's transitions in and out of the work force, Duryea, Lam, and Levison (2007) found that the probability of children entering the labor force, leaving school, and failing to advance to the next grade increases when the male head of household becomes unemployed. When households do not have access to the credit markets, the only way for them to smooth consumption is by sending the children to the labor market, reducing the time children spend at school or doing homework.

Paradoxically, positive income shocks can also be detrimental for academic performance and attainment. For instance, variations in coffee production in Brazilian counties (where coffee is economically important) can lead to an increased probability of working and of dropping out of school for low- and middle-income children (Kruger 2007). With better employment opportunities for the household, children would stay in school if the income effect dominates (education becomes more affordable). Nevertheless, children would be sent to the labor market if the substitution effect prevails (time for working becomes more valuable).

Birth order is another variable defining how parents allocate resources among their children. It would be expected that older children would receive higher parental investments, such as education. In the Brazilian case (Emerson and Portela Souza 2008), families tend to send their first-born offspring (regardless of their gender) to the labor market when facing poverty and capital constraints. The oldest children might be more productive in the labor market because they earn a higher wage. Family poverty may increase the parental preference for current consumption with a deleterious effect on children's human capital accumulation and future labor wages. The children's human capital accumulation depends on how their education improves the parental utility.

The decision to stay in school and to advance to college education may, ultimately, depend on the returns to education. In Brazil, there has been an increase in the number of students completing secondary education, paired with a decline in the returns to this level of education (Binelli et al. 2006). These two trends seem to be explained by an overall low quality level of high school education. The increased number of students has not been met by the provision of more schools and teachers.

III. Theoretical model

a) The foundations

The model in this paper builds on a theoretical model previously proposed to study the impact of access to water and sanitation on child health (Jalan and Ravallion 2003), which is also used in a propensity score matching application (Khanna 2008). In association with the originally proposed model, the children's health production function in this paper is added to the parental utility function. Notwithstanding, the model proposed in these pages deviates from the original model in five ways. First, it incorporates education as a variable in the parental utility function that, in turn, is a function of children's health levels. Second, it deals explicitly with the effect of access to water and sanitation services on the household's leisure time. Third, it posits that households have to pay a fee for using the water and sanitation services. Fourth, it also states that households have to pay for education. Fifth, is assumes that households do not value directly their expenditure on health; they only value it through the education achievement of their children.

The deviations from the original model can be easily justified. Education is valued in the parental utility function, because of the effects of children's education on parental welfare. Selfishly, parents care about the human accumulation of their children, expecting higher economic benefits in the future. A more contentious issue is not having the health function directly valued in the parental utility. The cited models did not have the health production function directly within the utility function. As the purpose of this paper is to explore the impacts of access to water and sanitation services on education, without loss of generality, it can be assumed that health only enters into the parental utility through the education levels of their children. It is not ruled out, but not considered in the proposed model, that the parental health level defines whether or not children go to school or affects their children's health condition.

It is assumed that access to water and sanitation may modify the leisure time and, consequently, the time allocated for income-earning activities. Poor access to water might force household members to spend time hauling, storing, or treating the water they need. Inadequate sanitary services could result in leisure time losses due to infections transmitted through contact with the excreta, or due to the time spent in the disposal of it (like in cleaning latrines). In order to keep the model tractable, leisure time is not included in the children's health production function. By doing this, it is assumed that parents allocate the leisure time of all household members in order to meet their economic needs and maximize welfare.

In our model, the utility companies charge the household for water supply and sanitation services. The fee will depend both on the quality and on the quantity of services supplied. Even if the services are freely provided, households still have to pay for connecting to the water and sewerage system. The same is true for education. The education fee depends on the amount of education children actually get. It is true that, for most families, education is freely provided by the government. However, although not facing tuition charges, households might end up paying education-related costs (e.g., paying for transportation, books, and related materials).

b) The maximization problem

This section introduces the model itself. It is assumed that households maximize a continuous double differential utility function $U(.)$, which is a function of education (D) of the children, a composite commodity good (X)), and leisure (l). Education (D) is a function of children's health production function ($D(h)$ with $D_h > 0$, $D_{hh} < 0$) and leisure (l) is a function of the measure of access to water and sanitation services ($l(q_{ws})$ and $l_{q_{ws}} > 0$, $l_{q_{ws}q_{ws}} < 0$,). The utility function is represented as follows:

$$U\big(D(h), X, l(q_{ws})\big) \quad \text{Eq. 1}$$

Children's health, $h(.)$, is a function of the measure of access to water and sanitation services (q_{ws}) and the expenditure on children's health (e). It is also continuous and twice differentiable with decreasing marginal returns on both the expenditure and on the measure of access to water and sanitation services. It is important to point out that q_{ws} stands for a measure of both quality and quantity of water and sanitation services. A priori, this variable indicates the type of services the household gets and, therefore, the quality of the water it consumes and the sanitary services it uses. Also, it is important to emphasize that q_{ws} affects a household's utility through the education and health of children, and through changes in leisure time. In sum, the children's health production function is:

$$h(q_{ws}, \mathrm{e}) \qquad \text{Eq. 2}$$

In all markets, households act as price (or fee) takers. They observe and pay the fees or per unit prices of the composite good (p_X), the education-related costs (p_D), and the fee charged for using the available water and sanitary services (c). Households divide their total time (in this case, a numeraire of 1 unit of total time), between leisure (l) and labor (L), such that $L + l = 1$ or $L = 1 - l$. When working in the labor market, households are paid a wage rate (r). Besides their income from work, households are also endowed with a monetary income (M). This can be savings, assets or any sort of cash transfer (independent from work) the household receives or inherited. Therefore, the household faces the following budget constraint:

$$M + r\big(1 - l(q_{ws})\big) = xp_x + p_D + e + cq_{ws} \quad \text{Eq. 3}$$

And thus, the maximization problem for the household is:

$$\underset{e, x, l, q_{ws}}{Max} U\big(D(h), X, l(q_{ws})\big) \qquad \text{Eq. 4}$$

$$s.t. M + r\big(1 - l(q_{ws})\big) = xp_x + p_D + e + cq_{ws}$$

c) The comparative statics

After setting up the Lagrange, the first and second order condition for a maximum are derived. Details of the maximization process and the comparative statics are fully presented in Annex 1. Here, and for purposes of presentation, only the most salient conditions are going to be explained.

One condition that is derived from the household model is related to the maximization itself. For a global maximum to exist:

$$\frac{h_{q_{ws}}}{h_e} - c < rl_{q_{ws}} - \left(\frac{U_{lx}}{U_{Dx}}\right)\left(\frac{l_{q_{ws}}}{D_h h_e}\right) \qquad \text{Condition 1}$$

The left hand side terms can be jointly interpreted as the net gain in children's health. The ratio of children's health improvement from the sanitary services to gains from the health-related expenditure, minus the cost of access to water and sanitary services. The right hand side is composed of three terms. First, the benefits from leisure time gained from improvements in water and sanitary services (valued at the wage rate, $rl_{q_{ws}}$). Second, the ratio of improvements in leisure to education from variations of the quantity of the composite good ($\frac{U_{lx}}{U_{Dx}}$). And third, and multiplying the second term, the ratio of gains in leisure from access to water and sanitation to the changes in education due to health-related expenditure ($\frac{l_{q_{ws}}}{D_h h_e}$). Households can improve the health of children either by accessing better water and sanitation services and by expending more on health (buying medicines, going to the doctor, better nutrition). They compare the health improvements to the fee they have to pay for being connected to the piped water and sewerage systems. Households also want to know the market value of their increased leisure time. From this enhanced leisure time, households discount the utility variations in leisure and education resulting from changes in the composite good. The term $\left(\frac{U_{lx}}{U_{Dx}}\right)\left(\frac{l_{q_{ws}}}{D_h h_e}\right)$ can better be understood as the changes in leisure and education (resulting from variations in the access to water and sanitation, as well as from the health expenditure) as households modify their consumption of the composite good. This term is subtracted from the market value of the leisure time to take into account how the marginal variations impact the overall level of welfare.

What does this condition mean? In a one-period model, like the one proposed, household members cannot fully capture the benefits of having more educated and healthier children. They care more about the immediate gains via their leisure time. In doing so, households need their leisure gains to exceed the gains from children's health and education. By having more leisure, households also know that labor participation decreases and, as a consequence, the income goes down, as well as the consumption of the composite good.

As for the comparative statics, only two effects are going to be explained below: the effect of the cost of water and sanitation services on the health-related expenditure ($\frac{\partial e}{\partial c}$), and on the measure of access to water and sanitation ($\frac{\partial q_{ws}}{\partial c}$). The first comparative statics, $\frac{\partial e}{\partial c} > 0$, implies that there is a positive relationship between the health-related expenditure and the cost of water and sanitation services. When water and sanitation services are more expensive, or their quality is deteriorated, water and sanitation consumption are reduced; then, households have to increase their expenditures on health protective measures (medications, better nutrition, medical check-ups, and other measures) to reduce the risk of sickness of their children. For this relationship to exist, the following condition has to hold:

$$rl_{q_{ws}} - \left(\frac{U_{xl}}{U_{xD}}\right)\left(\frac{l_{q_{ws}}}{D_h h_e}\right) > \frac{h_{q_{ws}}}{h_e} - c \qquad \text{Condition 2}$$

It is easy to be mistaken and confuse this condition with the condition for a global maximum. Actually, they are very different. The maximizing condition considers how the changes of the composite good relate to the gains in leisure and health caused by water and sanitation, and by health expenditure. However, Condition 2 actually can be approached from the expenditure side. Households spend their money on a connection and access fee, on health, on education and, finally, on the composite good. When the connection and access fee changes, expenditure on education and on health change accordingly and, in the process, impact the amount the household spends on the composite good.

The left hand side contains two terms. The first one stands for the market value of the enhanced leisure $\left(rl_{q_{ws}}\right)$. The second one represents the ratio of changes in the utilities of the consumption of the composite good caused by variations in leisure and children's education ($\left(\frac{U_{xl}}{U_{xD}}\right)$). This second term is amplified by another ratio: changes in leisure due to access to water and sanitation, to the changes in education due to health-related expenditure ($\frac{l_{q_{ws}}}{D_h h_e}$). In this condition, the focus is on how the utility of the consumption of the composite good is affected. Due to its impact on the income and on the money available, it is interesting to see for the household that the difference between the market value of the change in leisure (due to access to water and sanitation services) and the utilities ratio of changes in the composite good. In that sense, the net gain in leisure, discounting the variations in the consumption of the composite good, has to be greater than the net gains in children's health. If not, then, they will need to change their expenditure on health and on the composite good.

For an inverse relationship between the access fee and the quantity of water and sanitation services ($\frac{\partial q_{ws}}{\partial c} < 0$) the following has to be true:

$$q_{ws}\left[\left(\frac{U_{Dx}}{U_{xD}}\right)\left(\frac{h_{q_{ws}}}{h_e}\right)+\left(\frac{U_{lx}}{U_{xD}}\right)\left(\frac{l_{q_{ws}}}{D_h h_e}\right)\right] > 0 \quad \text{Condition 3}$$

In so far the cross derivatives are positive (in a smoothly continuous and double differentiable utility function they are expected to be so and also greater than zero) and the quantity of water is greater than zero, this condition will hold. The quantity of water and sanitary services are never zero because, even without a proper connection to the sewerage or water system, households will have some sort of consumption of water and sanitation services. They can either haul water from a river or well, use latrines, or even a share a water connection with other households. The discussion would get more complicated when the quality of the services is also considered. This is a very interesting case, because the signs can switch by including a quality variable, but as this variable is not available at the household level, such considerations are left for future research.

Another interesting point about this condition has to do with the cross derivatives. The cross derivatives between education and the composite good are amplified by ratio of changes in health from access to water and sanitation services, and from health expenditure: $\left(\frac{U_{Dx}}{U_{xD}}\right)\left(\frac{h_{q_{ws}}}{h_e}\right)$. This interesting result emphasizes how education and the composite good are rivalries for the income of the household. The other group of cross derivatives is composed by ratio of the cross derivatives between leisure and the composite good to the cross derivatives between the composite good and education. These are multiplied by the ratio of changes in leisure to changes in education from access to water and sanitation, and from changes in education due to health expenditure: $\left(\frac{U_{lx}}{U_{xD}}\right)\left(\frac{l_{q_{ws}}}{D_h h_e}\right)$. The relevant point is that changes in health are directly related to the changes in education and the composite good. Nevertheless, the changes in education have to relate with leisure. This is highlighting that health and leisure are intertwined in the education decision at the household level.

d) The hypothesis

Based on the results of the theoretical model and on findings in the cited references, the following hypotheses are to be tested in the empirical section:

> Hypothesis 1: Better access to water and sanitation services improves educational attainment.

Hypothesis 2: Sanitation services have a bigger impact on educational attainment than access to water.

Hypothesis 3: The oldest child will have less educational attainment, for given levels of access to water and sanitation services.

Hypothesis 4: Female children will have lower educational attainment, compared with male children regardless of the level of access to water and sanitation services.

Hypothesis 5: Children of more educated parents will have a higher educational attainment, regardless of the level of access to water and sanitation services.

Hypothesis 1 suggests that the access effect is expected to be positive because of the impact on health, on leisure time, and on the overall welfare of the family. Another element is the empowerment of the family, which suggests that having access to water and sanitation services makes the household feel belonging to a society and, as a consequence, boosts the desire to achieve higher welfare levels.

Hypothesis 2 posits that the impact of sanitary services is larger than the impact of access to water. This hypothesis emerges from the fact that Brazil still lags behind in the provision of sewerage systems, especially in rural and poorer areas. Furthermore, the contact with excreta can lead to a series of infections and diseases that offset the gains from better sources of water.

The rest of the hypotheses are related to sources of heterogeneity. Hypothesis 3 posits that the oldest children are sent to work. Once working, they do not have the time availability to advance and to perform well at school. The gender bias, Hypothesis 4, is related to the fact that female children are burdened with the housekeeping tasks, which may include water and sanitation (hauling and storing water, cleaning latrines). Finally, Hypothesis 5 offers a view into the issue of parental preferences over education. When parents are educated, they would have a strong preference for their children to achieve higher levels of education and to stay at school.

Before testing these hypotheses, the data and the methodology are explained below.

IV. Data sources

The empirical test of the hypotheses, drawn from the model and from the literature reviewed, is conducted by using the Brazilian Extended Questionnaire Census Sample 2010. This data is going to be supplemented by data on water systems, and a unique and novel variable: the number of rivers at the municipal level. The main sources for the data are the Brazilian Institute of Geography and Statistics (IBGE in Portuguese), and the Water National Agency (ANA in Portuguese). The file of the Extended Questionnaire Census Sample was obtained from the University of Minnesota's Population Center IPUMS-International project.

The model proposed, and to be tested in these pages, is a static (one time period model). It is true, and it is not ignored, that the effect of water on education can be of two types: instantaneous and accruing over time. After several years of exposure to non-potable water and to excreta, education is actually harmed when the health of children (or the change in leisure time) is such that they can no longer perform well in school. It is also possible that access to water and sanitation services changes over time, due to households' or provider's decisions. For instance, the water services can be suspended because the provider goes out of business, or because of permanent failure of the water and sewerage systems. Also, households may suspend their connection because of lack of payment, migration (from places with water and sewerage systems to places without), or because they simply do not repair the necessary equipment to make use of the water and sanitation services.

To test for the accruing effect of access to water and sanitation and for its changes over time, panel data would be necessary. In the case of Brazil, such a data set does exist but it does not easily report the location of the household. The location is absolutely necessary to control for a geographic measure of water availability and for the technical characteristics of the water systems at the municipal level. This information is crucial to disentangle the endogeneity bias. The Extended Questionnaire Census Sample, although not a panel data, provides the relevant location information and a wide array of information on household members and amenities. Combining the Extended Questionnaire Census Sample and measures of water availability, the goal of the empirical section is to estimate the total effect (both instantaneous and accumulated over time) of access to water and sanitation services on educational achievement. To do so, estimations were conducted for samples of children of different ages.

a) Individual data

The variables of interest for our analysis are related to education, age, gender and position in the household. The most important variable is the educational achievement, measured as the number of completed school years. It is likely that the education variable suffers from measurement error. Certainly, every individual clearly knows his or her educational achievements. There is no clear incentive to lie to a census surveyor about the level or the years of education. However, there can be a coding error. The Brazilian educational system went through several reforms, especially, in the labeling of primary and secondary education, which can inflict on the responses of different age groups. Such a measurement error may attenuate the estimates. This measurement error is also present in one of the independent variables, such as the education attainment of the head of the household. This variable is used to control for the preferences over education for the decision-maker at the household. The measure of educational level of the head of the household is preferred over the schooling of father and mother to take into account different family structures that deviate from the traditional father and mother present at home, as is the case in recent years.

The focus of the research is on children, because they are more prone to the contagion of infectious diseases due to poor access to water and sanitation services. In particular, two age ranges: from 6 to 15 years of age, and from 6 to 18 years of age are studied. Regressions will be performed, in most cases, for the sample of children aged between 6 and 10 years. Using these samples aims at identifying the effect that accrues over time. A gender variable will control for the expected bias against females. The position in the household will render a variable that will control for the oldest child in the household. This variable is intended to take into account any possible difference in the distribution of household resources among children, or in the decision of sending them to school. A variable to control for the race of the children is necessary to control for racial discrimination in educational attainment. Also necessary is a variable to take into account children with disabilities because of their different educational paths.

Table 1 shows for the main samples (6-15 years and 6-18 years) that children are on average 10 and 12 years old respectively. In the sample, 40% of the children are the oldest child in the household. The share of females in both samples is 48.9%. Forty-two percent of children identify themselves as of white race. Around 10% of all children reported various types of disabilities. Twenty-five percent of the children have lived in a different municipality than the current one. If their household has ever migrated, they have lived, on average, around six years in the current municipality. Children in the 6-15 years sample show an average of 2.7 completed school years. The average increases to 4.67 completed school years for the children in the 6-18 years sample.

b) Household data

This data allows for the identification of the current state and municipality of residences. Data also show whether the household is located in a rural area, which is important given the differences in the provision of services. Using the household-level data, it is found that 44.2% of children live in a rural household. Figures for the connection to the piped water system and the sewerage system are in line with the Brazilian realities. An 83% share of children in both samples have access to a piped water connection that is exclusive to their household, and inside their premises. Only 40% of children live in a household connected to a sewerage system. Electricity at home is enjoyed by 97% of children. Garbage is directly collected from the houses of 68% of children. Thirteen percent of children live in houses without bathrooms. Among other household features, the average size of the household is five family members. Interestingly, only about 44% of children live in a household headed by a male. The head of the household, regardless of gender, has an average of 6.4 completed school years. As a way to control for possible economic shocks or the health environment within the household, 1.6% of children reported the occurrence of a death in the family during the last year. All these figures can be seen in Table 2.

c) Water systems data

This part of the data is recorded at the municipal level. According to the Brazilian Constitution, the municipalities hold the responsibility of providing water and sanitation services. In reality, what happens is that state government owned and statewide water and sanitation providers deliver these services. The National Water Agency conducts an assessment of the water systems at the municipal level. The assessment, titled Atlas, is published every year, and it compiles all relevant information on water provision. The Atlas surveys all the water systems within the municipality and classifies them into isolated systems (providing water only to a municipality), integrated systems (providing water to more than one municipality), groundwater-sourced, or surface water-sourced. The Atlas also provides an assessment on whether the water systems need repairs, expansion, or finding a new source.

These variables are used as part of the instrumental variable approach. They signal water availability at the municipal level and, in consequence, the ease of the households to obtain better access to water and sanitation services. On average, it is assumed that households within municipalities that have underground-sourced systems often face difficulty in getting access to water and sanitation services. The reason is that those systems might be more expensive to operate, due to the cost of electricity for pumping the water. Water scarcity and other problems for access are also expected in municipalities in which water systems need to be expanded. An assumption cannot be made about the relationship between water scarcity and the type of water system, whether integrated or isolated. Isolated water systems can be more beneficial for municipalities because they do not have to share water resources with other municipalities. However integrated water systems can also be beneficial, because a municipality can share the costs of operations with other municipalities, and integrated water systems are easier to construct and to expand due to economies of scale.

A map of Brazil was used to calculate the number of rivers within the territory of each municipality. When a municipality has more rivers in its territory, it has more water available for the provision of drinkable water and for the operation of sewerage systems.[1] The assumption in this case is that more water availability raises the likelihood of connection for more households in the municipality. It can be argued that water availability is a necessary but not sufficient condition for access to water. In the end, systems have to be built, operated and technically maintained, and networks have to be expanded. Such processes may depend on regulation and political negotiation at municipal or state levels. This institutional mediation stage cannot be ignored. Nevertheless, assuming that municipal- and state-level governments care about the welfare of their citizens, they would be more apt to build water and sewerage systems. Water systems are easier and cheaper to build, if water is readily available at the municipal level.

Results have to be read with care because this paper deviates from the National Water Agency statistics. The National Water Agency of Brazil reports these variables for all water systems within a municipality. A municipality can have more than one water system within its territory. In this paper, the aggregation is made at the municipality level in accordance to the identification strategy. Despite this necessary aggregation, figures in Table 3 show that 42% of the municipalities have to pump their water from groundwater sources. Isolated systems are the rule in the country, as 86% of municipalities operate isolated water systems. The National Water Agency assesses that nearly 46% of municipalities need to expand their water systems. Water availability, proxied by the number of rivers, confirms the overall water abundance in the country (despite regional differences) since municipalities have an average of 40 rivers. In the larger municipalities of the northern region, the number of rivers can go up to 1,000.

V. Empirical strategy

The objective of this paper is to estimate the effect of access to water and sanitation services on educational attainment. Variables are created at the municipal, household, and individual levels. The identification strategy will combine these levels of information to find an estimator. Empirically speaking, the goal is to use a technique that offers an estimator that can be read as a causal relationship. That can only be accomplished by addressing the endogeneity existing between access to water and sanitation services, and education.

a) Endogeneity bias

There is a correlation between access to water and access to education. Some municipalities can score well on both, providing access to water and sanitation services and, also, on the educational attainment of the residing children. An opposite situation can also be true: there exist municipalities with low provision levels of both education, and water and sanitation services. Observed and unobserved factors can be causing this correlation. A good example would be the quality of institutions or the incentives to provide services that translate into the inhabitants' welfare and economic development. In this case, the institution quality variable might be explaining both access to water and sanitation services, as well as the educational achievement (via education supply). The existence of such a correlation makes it impossible to establish a

[1] The use of number of rivers within the territory of a municipality may not be sufficient to capture water availability to that municipality since: (1) flow can vary among rivers, and (2) rivers can be shared among municipalities. At this stage, we will stick to the suggested measure of number of rivers, but we look into data that will allow us to measure long-term mean flow in each river, and number of riparians that share the water in the various rivers. These two measure will allow us to create a variable that measure water availability to a municipality.

causal relationship between access to water and education achievement by using simple OLS regressions.

Access to water and sanitation is not randomly assigned. Water systems investments are not undertaken randomly across municipalities. Moreover, the connection decision at the household level is not random either, and it might be a function of parental preferences over health and use of leisure time. If the assignment of the construction of the water and sanitation systems were random, municipalities with access to water and sanitation systems would be almost identical to the municipalities that are not getting those. If so, then institutional quality differences would be eliminated and differences in educational achievement can be read as a causal relationship. The same is true at the household level: if the connections to the water and sanitation system were random, households that connect would be almost identical to the households that do not connect. All the differences in preferences over health and education, and any possible unobserved factor would be eliminated. The only remaining difference would be in terms of educational attainment of the children of families whose households are connected to the water system.

This endogeneity bias is explained by simultaneity and omitted variable bias. By simultaneity, we mean the high correlation between water and sanitation services with education. By omitted variable bias, we mean a self-selection into the access to water and sanitation. Self-selection takes place at both municipal and household levels when unobserved variables (institutional quality and parental preferences over human capital accumulation) lead to a government's decision to build the water system and the subsequent household's decision to connect.

In the presence of endogeneity, it would be ideal to use a panel data at the household level that, provided the information on the location, can be used to get rid of the unobserved variables at the household and municipality level. The other solution would be to find proxy variables to control for institutional quality, and for parental preferences over health and education. The choice of those proxies is complicated: first, those variables may not exist for all municipalities across the country; second, those variables can be actually unobserved and any proxy could be biased; and, more severely, there can be a full set of those variables, and not all of them can be available. For a true policy recommendation, based on an actual causal relationship between access to water and sanitation services and schooling, the instrumental variable approach is preferred.

Instead of using one instrumental variable, this paper employs a set of variables controlling for water availability and ease of connection at the municipal level. The goal is to control for those variables that define the process of providing water and sanitation systems to the population (the supply side), and the process of connecting to such systems (the demand side). The variables describing the water systems (source type, integrated or isolated, and whether or not it requires an expansion), the geo-physical variable of water availability, and the number of rivers in each municipality are the set of instruments that can be used to tackle the endogeneity problem. It would be ideal to have the water flow of the rivers within the municipality for a more accurate estimation of water availability. Such estimates are not available for all the municipalities in the country.

Even more, in theory, the instrumental variables should not be related to the dynamics of the education provision and demand. This approach is similar to the approach in a paper exploring the relationship between access to water and mothers' outcomes (Koolwal and van de Walle 2010). The authors, even though not using an instrumental variable, exploited the geographical differences for infrastructure placement. For their results to hold, they assumed that the relevant characteristics influencing infrastructure and outcomes were controlled by their geographical variables and, therefore, infrastructure placement is random.

Covariances and correlations, presented in Table 4, indicate that the choice of instruments is satisfactory. The instrumental variables, either by using all or by using the principal component of all of them, have a high correlation with the access variables and a low correlation with the schooling measure. The principal component variable was obtained from the factorial analysis of the source, type of system, enlargement need, and number of rivers. The KMO statistic is 0.5175, which is very low and will lead to read with caution the econometric results when using the principal component instrumental variable. Principal component analysis, at the end, attempts to address the problem of an omitted variable that explains the variations of the chosen variables. Perhaps, the KMO statistic using water system features and water availability is low because what is actually missing is a variable for the institutional stage that defines the provision of water and sanitation services. Finding and using such a variable could be the goal and the method of future research.

b) Identification strategy

The identification strategy relies on the municipality of residence of the household. That municipality of residency is used to instrument the connection to the piped water system and the sewerage system at the household level. It is important to remind the reader that the regressions are carried out at the individual level: for each child in the household. The location of the household is the necessary criteria for identification, because it is assumed that children do not take part in the residency decision of the household. In that respect, the location might be taken as exogenous to the children, as well as the availability of piped water, and sewerage systems.

There are statistically significant differences in the mean of the completed years of education, when comparing the group of children connected to the water and sewerage systems to the group of children without such a connection (Table 5). The t-tests do not address the problem of endogeneity and simultaneity. They point at the existence of a significant difference that has to be further depurated by controlling for other individual and household level variables.

As every strategy of identification, this one might also suffer from some weaknesses. The main weakness is related to household migration across municipalities and across states. During the lives of the children, their households can be moving around the country, and they can be exposed to different levels of access to water and sanitation services. If this happens, and assuming that access to water, sanitation, and education is a main driver of household migration, the sample will not be representative: households exposed to poorer access conditions are underrepresented and households that are exposed to better access conditions are overrepresented. Any estimator would be biased upwards, because the sample is composed of people living in municipalities with higher provision levels of water and sanitation services (and education too). This threat is controlled by including a variable measuring the time the household has spent in the current municipality.

Perhaps, and more relevant, it is certainly possible that households migrate in and out of water and sewerage systems. This means that households can experience a pattern of connection and disconnection. When this happens, children are exposed to different types of water for consumption and different sanitation facilities. Even though this is exogenous to the children, it is also true that this transition might have a deleterious effect on health over time, and may bring about some transitory changes in leisure time that end up harming academic performance and school enrollment. Such a pattern reduces any possible positive effect of the access to water and sanitation on education. It operates as a force pulling towards zero any possible effect. It would be ideal to have data on the connection history of the household, but that data does not exist.

Even though Brazil is a country endowed with huge natural resources, water and sewerage systems may have a poor service quality. Due to low maintenance, water systems may not operate continuously throughout the day or throughout the year. Moreover, the quality of the water may not constantly meet the standards set by the regulatory agencies. In addition, children may be exposed to excreta at home or in their neighborhoods because the sewerage systems malfunction or do not operate constantly. Measures of quality of the piped water and sewerage systems and of users' satisfaction are not readily available for all the municipalities in the country. Anecdotal experience indicates that the problems of service quality and reliability also reduce any possible positive effect of access to improve water and sanitation services. Issues of service quality and reliability may take the estimation of the effect towards negative values.

Children spend part of their time at home and another part at school. The sanitary conditions at school are also important for children’s academic performance. Figures from the 2011 National School Census, provided by Qedu (www.qedu.org.br), call into attention how serious the problem of school-level access to water and sanitation services is. Out of the total 194,932 schools in the country, only 67% are connected to piped water systems and, even more concerning, only 43% are connected to a sewerage system. Schools funded by the municipalities are in a precarious condition: only 54% are connected to a piped water system and only 29% are connected to a sewerage system. That compares to the almost 100% on both items for private schools. What happens to the educational performance of children that have good water and sanitation services at home, but that do not have them at school? Based on proposed theoretical model (Section III), households would be forced to spend more on health-related items or services in order to overcome any possible negative impact of the sanitary conditions at school. This threat to the identification strategy is far beyond the reach of this paper. Where does the access to water and sanitation services matter the most: at home, or at school? To answer this question the variable for the access at school is also needed. Unfortunately, that variable cannot be matched with the Census data.

Finally, the cited literature and the theoretical model mention health as one of the channels through which access to water and sanitation services affects educational performance. Children with poor health will underperform due to their waterborne diseases. However, children that died because of waterborne diseases are not in the sample, and their school attainment is unknown. The children in the sample are those that survived the waterborne diseases and, therefore, they obviously have more years of education. Ideally, a data set would contain the death cause of the child, and it would be easier to classify those who died of waterborne diseases. That variable is not available. To sort out this problem, the estimating equation will include a dummy variable for the death of any family member over the last year, to take into account some sort of family health setting.

c) Estimating equation

After describing the problem of endogeneity, the identification strategy and the threats to identification, we present next the equation used to carry out the estimation:

$$Education_{ihm} = \beta_0 + \beta_1 Access_{ihm} + \Lambda_{ihm}\beta_2 + \Pi_{hm}\beta_3 + \theta_m + \varepsilon_{ihm} \quad \text{Eq.5}$$

$Education_{ihm}$ is the level of education achievement (school attainment) of child i, member of household h residing in municipality m. The measure of access, $Access_{ihm}$, controls for the type of access to water or to sanitation service at the household of the children. Λ_{ihm} is a vector of individual level variables, such as age (and age squared to take into account any possible diminishing returns), gender of the child, position among siblings (whether or not the child is the oldest), race and if the child has a disability. Π_{hm} includes information about the educational level attained by the head of the household, whether or not the household has ever migrated, the occurrence of the death of a household member during the previous year, and whether or not the household dwells in a rural area. θ_m is the municipality fixed effect. Finally, ε_{ihm} is a random disturbance.

This equation includes sources of observable heterogeneity related to education decisions in the households. If resources are not equally distributed among children, controlling for the oldest children and for the female in the household will properly reveal such patterns. Another source of heterogeneity is the distribution of preferences across households over the education of their children. For instance, a more educated head of the household will invest more in the education of the children regardless of their environmental conditions. He or she may value the positive effects of education on life (better job opportunities, better wages and higher life standards) since he or she may be already experiencing them. Another source of heterogeneity is related to the migration pattern at home. Even though children of households that have always lived in the same municipality can be exposed to different levels of access to water and sanitation services, those variations are essentially different from those of children that have lived in different municipalities throughout their life. Finally, a dummy variable for the occurrence of a death in the household during the previous year may be a proxy for the overall health environment of the household and for an income shock. Health cannot be directly controlled given the data, but this death variable may point out that deaths occur in households that had lower health levels and, therefore, where children are not fit to perform well at school.

Household fixed-effects cannot be used, because all children in the household receive the same treatment (the same level of access to water and sanitation services) at the moment of the survey. If these fixed-effects were used, they would get rid of all those unobservable effects at the household level that are constant over time. For such purposes data would have to provide information of the household at different time periods. That is not the type of data to be used in this paper. As a result, municipality level fixed-effects are going to be employed. By doing so, the unobservable effects at the municipality level are going to be controlled. The remaining question is what happens with the unobservable effects at the household level. It is expected that parental education and time residing in the municipality, if not completely purging out, will at least reduce the influence of the household-level unobservable effects.

Interestingly, the municipal level unobservable effects might be related to the institutional unobservable effects. The geographical, natural, and technical features of the water systems, which are external to the households, will be controlled for in the instrumental variable equation (in a 2SLS setting).

The variable created for the type of access to water and sanitation services, $Access_{ihm}$, is instrumented by using the following regression:

$$Access_{ihm} = \begin{matrix} \alpha_0 + \alpha_1 GroundWater_{hm} + \alpha_2 Isolated_{hm} + \alpha_3 Expansion_{hm} + \alpha_4 Rivers_{hm} \\ +\alpha_5 OwnedHome_{ihm} + \alpha_6 Electricity_{ihm} + \alpha_7 NoBathroom_{ihm} + v_{ihm} + \end{matrix}$$

Eq. 6

$GroundWater_{hm}$ is a dummy variable for those water systems fed by groundwater sources. If a system is an isolated system, the variable $Isolated_{hm}$takes a value of 1 (and zero otherwise). When the water systems within the municipality needs an expansion (according to what ANA assesses in the Brazilian Water Atlas), the variable $Expansion_{hm}$ is equal to 1 (and zero otherwise). The geographical measure of water availability, $Rivers_{hm}$, stands for the number of rivers within the municipality territory. Some household variables are also needed to identify the system and to be able to use municipality-level fixed effects in the second stage. When the family owns the home in which it dwells, $OwnedHome_{ihm}$takes the value of 1 (and zero otherwise). $Electricity_{ihm}$ controls for the connection to the electric grid. Finally, $NoBathroom_{ihm}$ takes into account the existence of a bathroom within the dwellings.

Standard errors of the estimators are clustered at the municipal level. As the treatment is proposed to take place at the municipal level, standard errors can be independent across municipalities, but still clustered within each municipality. If clustering is not performed, the true standard errors are underestimated, and the null hypothesis will tend to be over-rejected. As Brazil has more than 5,000 municipalities, regressions will not have the problem of having less than 40 clusters, which seems to be the rule of thumb when clustering.

The interpretation will focus on β_2. This estimator can be read as causal if the instrumental variable approach and the municipality level fixed-effects remove all those omitted variables that are correlated with both the educational attainment, and the access to water and sanitation services. Fundamentally, they will remove all the omitted variables that do not vary over time, either observable or unobservable. The only remaining variables that might undermine the causal relationship are those that change overtime. Such variables are not a reason for concern, since this paper uses data for only one year.

β_2 is also a total average affect. It is a total effect because, by the assumptions presented in the proposed model, it is estimating the combined effect on education of the changes in the use of leisure time and of the children's health due to the type of access to water and sanitation services. Given the data, there is no way to disentangle both effects. Perhaps, anthropometric measures for every child in the sample would be needed. It would not be possible to properly identify the instantaneous and the accumulated effect. It is intended to show the pattern over time by carrying out the estimation for different age ranges. Finally, the effect is average at the municipal level, due to the use of the municipality-level fixed effect.

VI. Estimation results

For the sake of presentation, Tables 6 and 7 contain only the estimators of the effect of the access to water (connection to the piped water system) and the effects of the access to sanitation services (connection to the sewerage system). Tables with all model estimators are available upon request. Regressions were conducted using the main two samples – children aged between 6 and 15 years, and children aged between 6 and 18 years – but a sample of children between 6 and 10 years of age was also used for comparison purposes. The use of the instrumental access measures (Equation 6) was obtained either by a linear probability model or a logit regression. As a robustness check, samples are split in half, by using the logit instrumental access variable: if instrumented access was less than the median of the variable distribution, then 0 is assigned. This is a way to explore the situation when only 50% of households have access to either service. Results can be read in terms of years of education or in terms of days of education, if multiplying the coefficient by 200 (officially, the school year in Brazil is 200 days).

Even though not presented here, some words about the control variables are worth mentioning. The variable for gender indicates a bias in favor of female children when it comes to educational achievement. Females tend to have, at most, 0.3 more years of education than their male brothers. The oldest child in the household studies around 0.006 more years than the younger siblings (for the 6-18 years sample). There is a slight, but significant, unequal distribution of resources giving preference to the education of the oldest child over the other offspring. Another source of discrimination comes from race, since white children attained, at least, 0.13 more years in school when they are supposed to finish high school. Disabled children have less schooling in all regressions. As expected, the coefficient of the education of the head of the household is positive, even though small (at most 0.06 more school years). Children living in households that migrated have 0.04 more school years than children always residing in the same municipality. The variable controlling for the occurrence of a death within the household, intended to control for the overall health environment within the household, shows a negative, yet small, impact on the number of completed school years. This may indicate that households have to reduce their education-related spending after the death of a member, or that health is poor for all household members. Finally, children residing in rural areas have almost 0.12 less school years, perhaps due to their employment in farm activities. Overall, the signs of the coefficients are in line with what has been previously found in the literature. The coefficients of the access to water and to sanitation services, to be discussed below, are presented in Table 6 and Table 7.

a) Impact of access measures without instruments

This first coefficient shows how pervasive and harmful the endogeneity can be between the measures of access and educational achievement. Without using fixed effects or instruments (Panel A Table 6), the impact of access to water goes from a positive 0.104 years (for the age 6-10 years sample) to a 0.447 more years of education (for the age 6-18 years sample). When using fixed effects but not instruments (Panel A Table 6) the point estimates are subtly reduced: 0.094 (6-10 years sample) and 0.342 (6-18 years sample). Estimates for the 6-15 years sample always fall between the other two samples, indicating an age-dependent path that is present throughout the regressions. Point estimates are smaller for the effect of access to sanitation services (Panel A Table 7). Without fixed effects nor instruments, it is found that access to sanitation has a negative impact on the schooling of the 6 to 10-year-old children. The same age pattern, an effect that grows with the age of the children, is clearly seen in the estimates for the impact of the connection to the sewerage system.

b) Impact of access measures using a linear probability model instrumental first stage

Panel B, of both Table 6 and Table 7, shows the first instrumental attempt on estimating the coefficients of the effect of the connection to the piped water and to the sewerage system. Here, a linear probability model is estimated in the first stage regression. Reading the point estimates, the impact of the connection to sewerage is larger than the effect of the connection to the piped water for the full sample. Households need to be educated about other sources of water pollution within the dwellings (Khanna 2008). Also, contact to excreta can be more harmful in transmitting diseases for children. The burden of the diarrhea diseases on children's health and on the family time can lead to reduced performance at school. Not only caregivers have to reallocate their time, but it may be that the possibility of contagion for the other children increases once a sibling is suffering from diarrhea. Effects seem to have a positive relationship with the age of children, an accumulated effect that was discussed earlier. The impact seems to have diminishing marginal returns, growing at a decreasing rate. Point estimates are very similar when using all instruments of the water systems and water availability, or using the principal component. Ignoring endogeneity leads to severely underestimate the impact of access to water, but even more, the impact of the access to sanitation services. Figures may suggest that the country needs to accelerate the expansion of the sewerage systems as a way to also reduce education inequalities that may translate into permanent gaps of human capital accumulation. It appears that expanding the sewerage systems would be a good way to cut the vicious cycle of inequalities throughout the country.

c) Impact of access measures using a logit instrumental first stage

Panel C of Table 6 and Table 7 is what can be considered the best set of estimates for this paper. The advantage of the logit first stage is that it bounds the fitted values of the first stage between 0 and 1. Point estimates of the effect of connection to the piped system remain almost the same. Estimates also exhibit the diminishing marginal returns on schooling as children get older. The figures imply that the government needs to guarantee access to water and sanitation services during the early school years of the children. In this way, governments can maximize the benefits from the investments in water and sewerage systems, the conditional cash transfers, and the programs aimed at improving the quality of education and increasing enrollment. The effect of the sewerage system seems to be consistently higher than the effect of the access to water and sanitation services. The accumulated impact of reduced exposure to excreta, in terms of healthy days throughout school life, and more time available for leisure, is of a significant magnitude: around 0.8 school years or 160 school days for children aged 6-18 years. The connection to the piped water system, with a positive impact of 0.7 school years (140 school days) is relatively smaller. Nevertheless, access to water may highlight the use of time within the household and the practice of amenity habits (like hygiene, cleanliness, and good nutrition) that are important for school performance.

d) Impact of access measures using a censored transformed logit instrumental first stage

These regressions (Panel D of Table 6 and of Table 7) are the empirical answer to the assumption that 50% of children live in households connected to a piped water system or a sewerage system. Given the sample, this implies reducing the overall access to water (from 83% to 50%) and increasing the overall access to sanitation services (from 40% to 50%). It was expected that the effect of the connection to the piped water increased, while the effect of the connection to the sewerage system decreased. The expectation does not work in terms of access to water because, actually, the point estimates get smaller. Expectations do work for connection to the sewerage system as the point estimates get smaller and only top a 0.1 additional school year for the 6-18 years sample. While Brazil seems to have reached the maximum possible benefits from connection to piped water systems, social differences can be ameliorated by expanding sewerage systems. For such an expansion to take place, the government needs to tackle legal, regulatory, and economic obstacles that slow down the investments and the institutional bargaining for carrying out the expansion where is most needed: rural areas, and the poor north and northeastern parts of the country.

e) Impact of joint access measure

A dummy variable was created taking the value of 1 if the child lives in a household that is connected to both piped water system and sewerage system (and zero otherwise). In the sample, around 39% of children live in households connected to both services. Living in households only connected to the piped water system takes a share of nearly 48% of children, while only connected to the sewerage system has a share of 1%. Children living in households not connected to neither piped water nor sewerage system represent around 12% of the sample. Point estimates are presented in Table 8. Panel A shows, again, how pervasive endogeinity can be. Panel B, using a linear probability model in the first stage estimation suggests an impact that grows as children get older, but with diminishing returns. Panel C, using a logit model in the first stage regression, can be considered the best estimate of this robustness check. It is important to highlight that it may seem that the effects are driven by the connection to the sewerage system. Point estimates are higher than the effect of connection to water, but very close to the estimates of the impact of the connection to the sewerage system. These results may indicate that water itself is not enough, and that the connection to the sewerage system really represents a plus in the welfare of children. The age path calls for the government to guarantee the access early in life to obtain the maximum benefits. Without joint access to water and sanitation services, it seems that the inequalities in human capital, and later labor market performance, may be hard to overcome.

VII. Conclusions

Brazil is a country endowed with vast natural resources and, among them, water resources. The country has made real progress in the access to improved water quality and drinkable water, but it has not progressed in providing access to improved sewerage systems. The provision of water and sanitation services falls within the responsibility of the municipality, but it is the rule that those services are mainly provided by publicly owned statewide utilities companies. The history of water and sanitation provision seems to be divided by the National Sanitation Plan (PLANASA) that preferred water over sanitation services. Following the PLANASA, the country is facing the challenges of expanding and updating the water and sanitation systems and enforcing regulation on maintenance and operation.

Previous research has stressed the positive impact of access to water and sanitation services on the health of children. Better access prevents children from getting waterborne diseases or diseases related to contact with excreta. With better health, it is assumed that children can perform better at school and achieve higher levels of education. Better health at home also allows for parents to engage in income-earning activities. When households are connected to improved water and sanitation services, children spend less time hauling and storing water, and mothers have more time to participate in the labor market. Deficient access seems to have a negative gender bias, taking a toll on the education of women at home. As for Brazil, previous studies seemed to ignore the problem of endogeneity. Overall, the country has experienced an expansion of school attendance due to conditional-cash programs and fast economic growth.

The goal of this paper was to estimate the impact of access to water and sanitation services on education attainment, measured as completed years of education. For this, a theoretical model was proposed, which incorporated the access to water and sanitation through the household's leisure and the health of children into a household utility function. The model includes the children's education achievement, which depends on their health levels. Interpreting the comparative statics, the effects are conditional on the attributes households assign to the education and health gains in relation to the cost of access, and the market value of changes in children’s leisure time. Since households cannot fully capture all the health and education gains of their children, they compare those gains to changes in their consumption of the composite good.

The results imply that children living in a household connected to a piped water system are endowed with 0.7 more school years (140 school days), and that children connected to the sewerage have an educational achievement of 0.8 school years (160 school days) higher compared to those children living in households lacking these services. Data revealed that the educational achievement of the head of the household matters in the schooling of children. More importantly, data confirm typical sources of discrimination in terms race, location in rural areas, and age within the household. The occurrence of a death during the previous year reduces the number of years of education, which highlights the relevance of controlling for the household's health environment and economic shocks. These results can be read as a lower bound, because the access to water and sanitation services at the school cannot be controlled for and also because there might be a measurement error in the schooling variable, as was indicated earlier.

The immediate effect of poor access to water and sanitation is either not completing high school or failing to obtain higher education. Assuming a working life span of 40 years, a study (Holanda Barbosa Filho, F. and Pessôa 2008) estimated that the wage premium of completing 11 years of school was 34.3%, and that the internal rate of return (IRR) for the same school attainment was 28.8%. In that sense, our lower bound estimate of 0.8 years schooling differential, due to access to water and sanitation, represents a net loss to the individuals. First, they may have to invest more in education in order to catch up later, which reduces the internal rate of return. Second, they may graduate later on and, therefore, postpone enjoying the benefits of schooling, which will result in a lower net wage premium and a lower IRR.

Estimates provide evidence to accept Hypothesis 1, namely that access to water and sanitation services improves schooling attainment, measured in completed years of school. Hypothesis 2 is also accepted because, based on the point estimates, the impact of access to sanitation services (connection to the sewerage system) is larger than the access to drinkable water. The oldest child in the household has completed more school years than his siblings (after controlling for age), which supports Hypothesis 3, even though the value of the point estimate is very small. Rejecting Hypothesis 4, female children, regardless of their access to water and sanitation services, attained higher schooling levels than male children. As for Hypothesis 5, the education of the head of the household matters, and has a significant positive impact on the education of children in the household.

The Brazilian government may need to spend US$92 billion by 2020 to achieve the goal of universal coverage (Heller 2006). Although an elevated figure, returns from such an investment program will translate into more future labor productivity and less social inequalities by closing human capital gaps. The challenge of expanding sanitation services, sewerage systems in particular, will require the design of programs that allow for point-use technologies, which can be very relevant in rural areas (Galvão Junior 2009). Coverage at the household level needs to be intertwined with coverage at the schools. A high-quality education is a system that provides both the educational services and water-related amenities that children need to be healthy and productive. Assistance programs for households that have suffered the death of a member might be directed towards improving the health environment or to smooth.

This paper opens up an interesting and exciting research agenda for studying the relationship between access to water and sanitation services in Brazil. For instance, future research can estimate the impact of access measure at school on the performance in the Prova Brasil. For this, scores at the individual or school average measures can be used. When available, a panel data at the household level should also be used to try to control for changes in access to water over time. Furthermore, if time use data and anthropometric variables are available, researchers should next try to disentangle the effects of operating through the health and leisure channels. Future research should also identify the instantaneous and accumulated effects.

Even though the positive effects would call for spending more on the expansion of access to water and sanitation services, more funding is not the solution. The Brazilian government first needs to sort out the institutional issues that are preventing more private capital participation in the sector. Additionally, more needs to be done to reduce the losses and to technologically update the current systems. Better regulation and planning is needed to keep systems fully operational, and to reduce instability in the service delivery. Emphasis will have to be placed on the poorest regions of the country and in the rural areas. In a country of continental dimensions like Brazil, one technology "does not fit all." Alternative technologies will have to be employed to achieve the goals of universal water and sanitation coverage.

Endnotes

[1]: The Brazilian Sanitation Act (Federal Law 11.445/2007) states that sanitation services are composed by: water, sewerage treatment, and garbage collection. Garbage collection is also very important for the health and welfare of children. The exposure to garbage may lead to infectious diseases too. Here, garbage collection is not addressed, because there seems to be no ideal instrumental variable to sort out the endogeneity problem that such a service might have with education.

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Graphs and tables

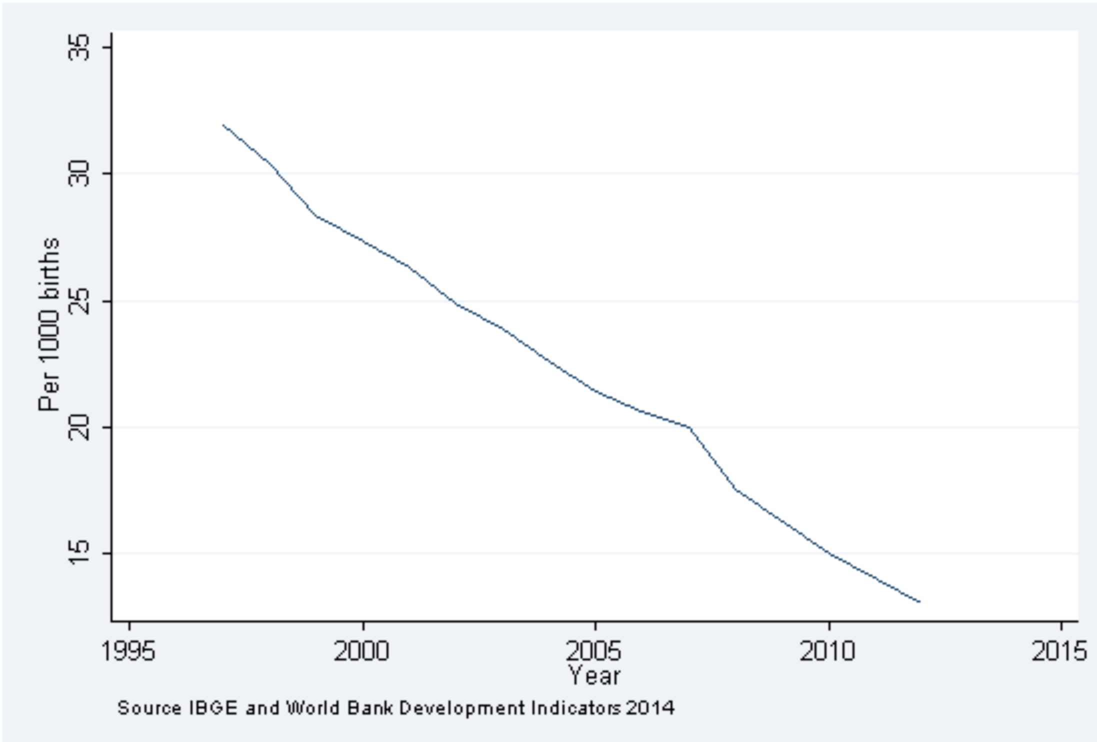

Figure 1: Brazil's infant mortality rate

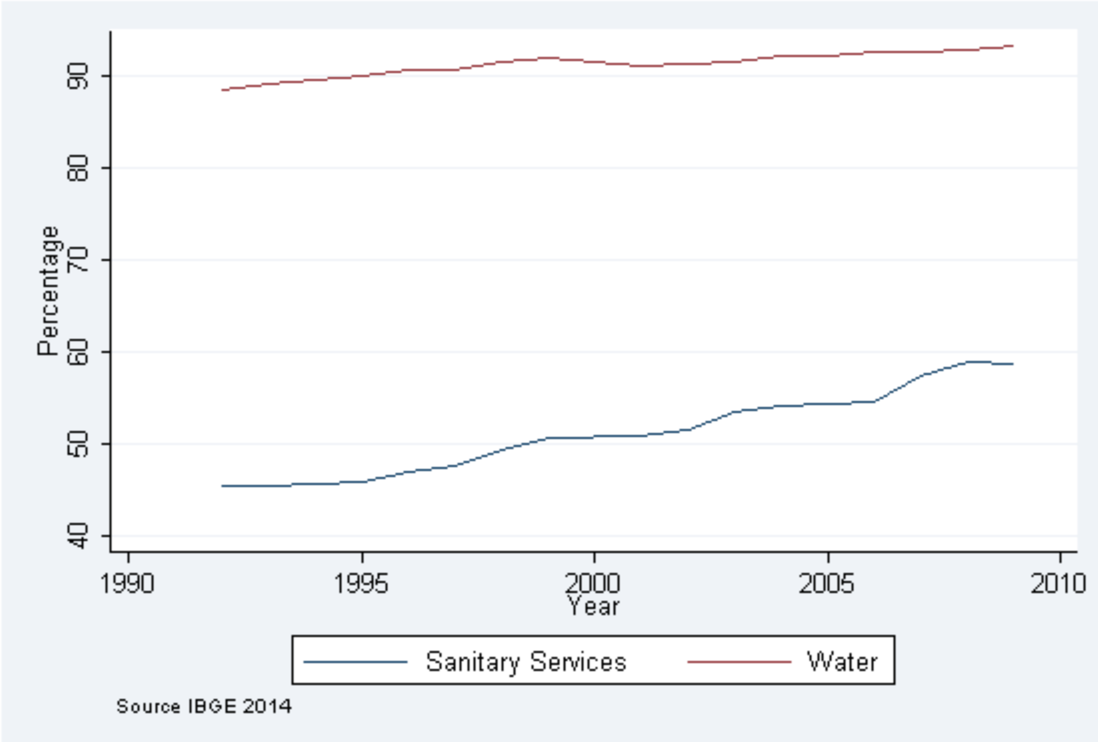

Figure 2: Access to water and sanitary services in urban areas

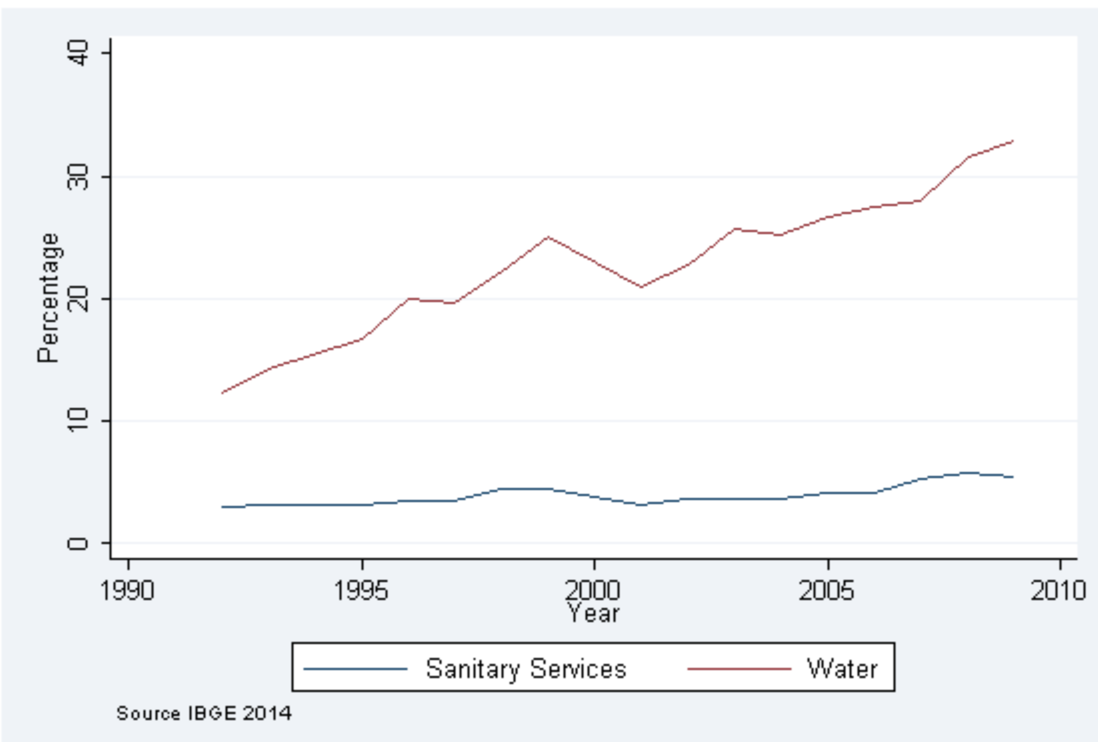

Figure 3: Access to water and sanitary services in rural areas

Figure 4: Percentage of child mortality caused by diarrhea

Figure 5: Hospital admissions due to fecal and orally transmitted diseases

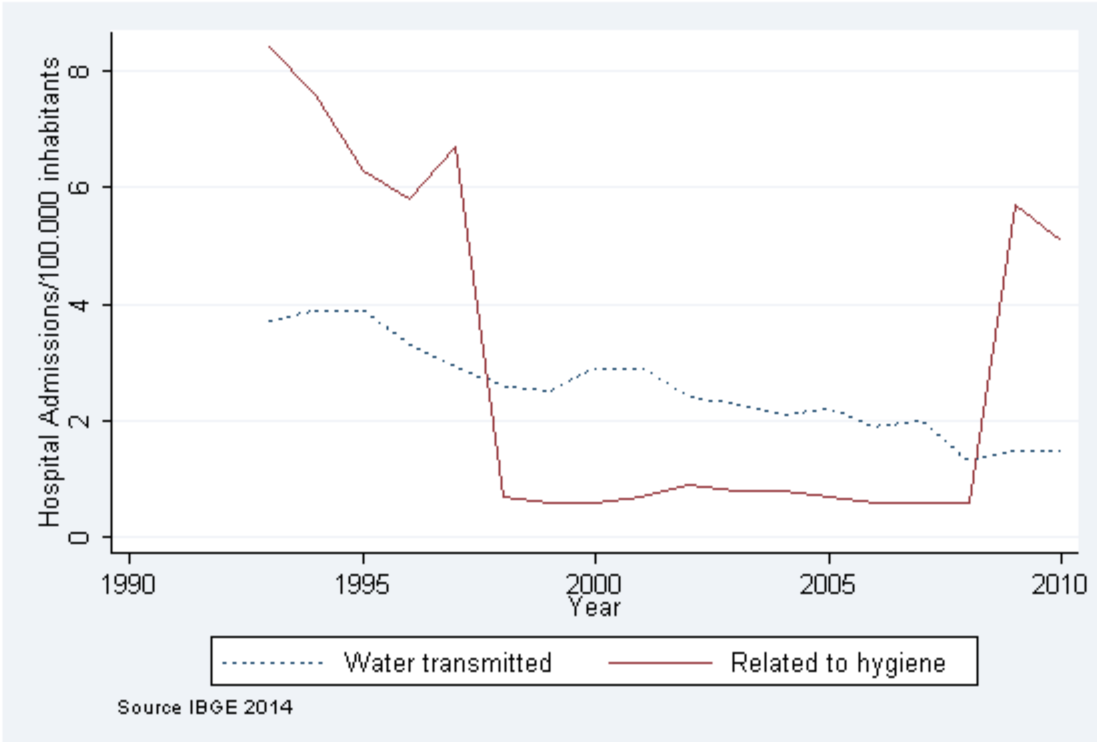

Figure 6: Hospital admissions due to hygiene and water transmitted diseases

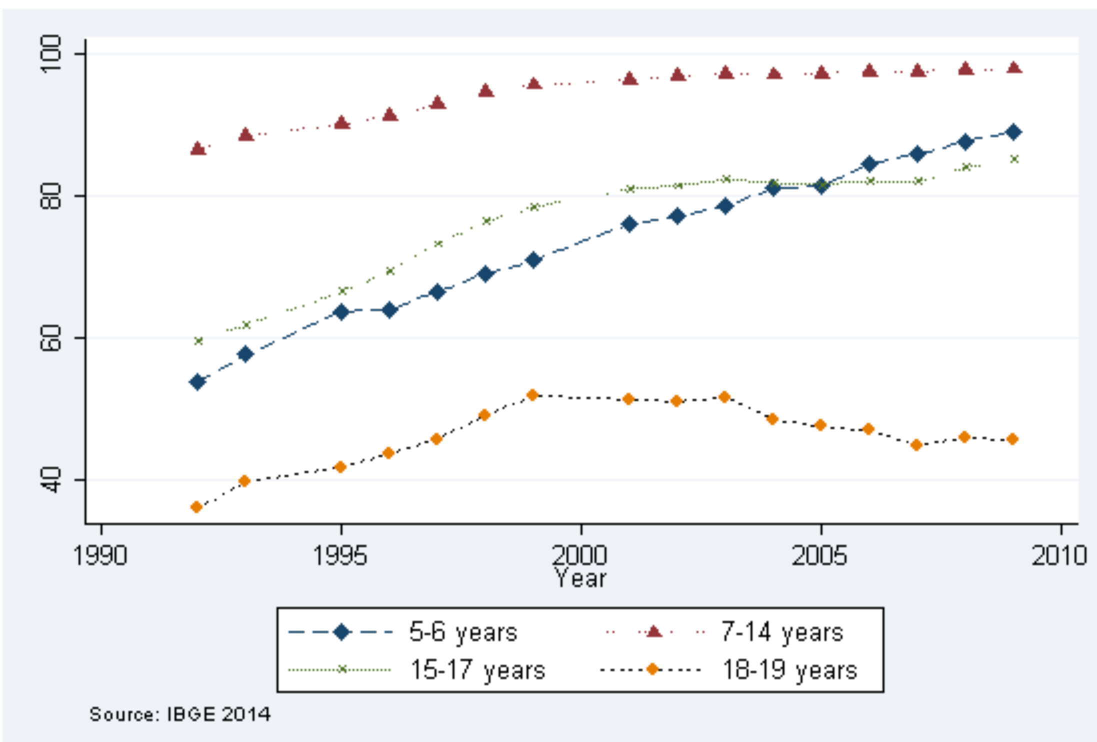

Figure 7: Brazilian enrollment rates by age groups

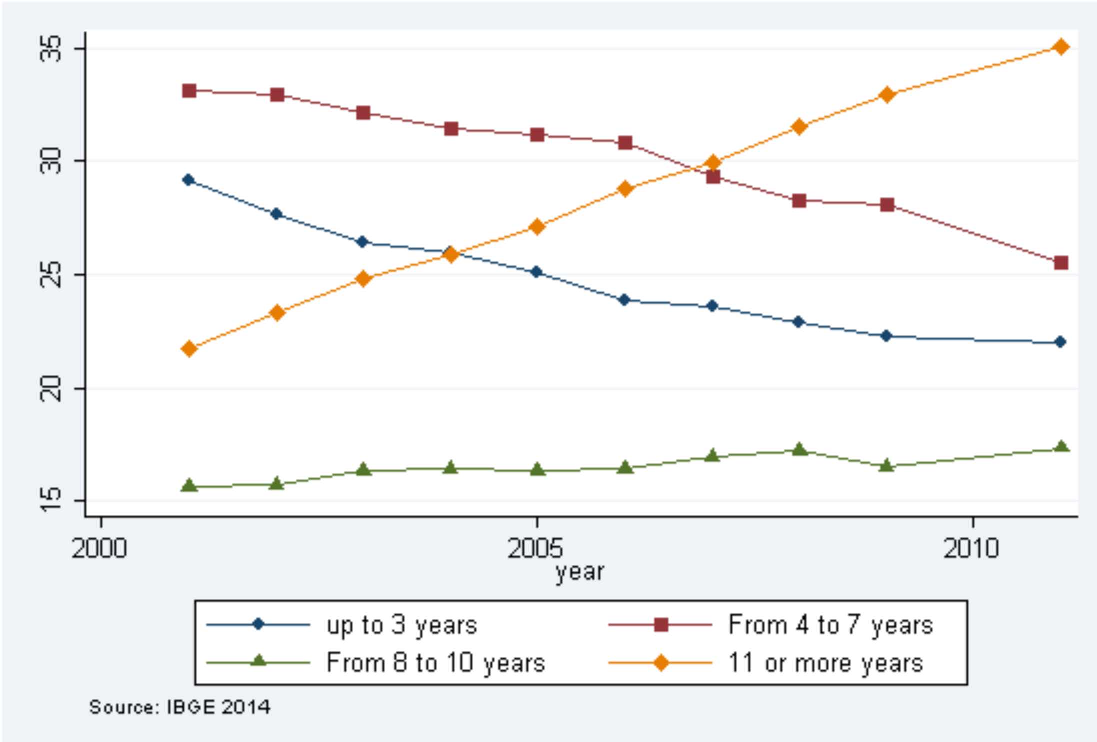

Figure 8: Number of completed school years of citizens 10 years and older

Table 1: Individual level characteristics

Variable	Sample 6-15 years			Sample 6-18 years		
	Obs.	Mean	Std. Dev	Obs.	Mean	Std. Dev
Age	1727270	10.69	2.849	2257010	12.169	3.674
Female	1727270	0.489	0.5	2257010	0.489	0.5
Member of an indigenous group	1727129	0.008	0.087	2256828	0.007	0.085
White race	1727129	0.419	0.493	2256828	0.42	0.494
Reporting a disability	1727103	0.098	0.298	2256780	0.102	0.302
Oldest in the household	1727103	0.402	0.49	2256780	0.428	0.494
Has ever migrated	1727270	0.236	0.425	2257010	0.25	0.433
Years resided in current place if ever migrated	407327	6.176	4.333	563141	6.859	4.995
Can read and write	1727270	0.892	0.31	2257010	0.912	0.283
Schooling (years)	1727270	3.532	2.703	2257010	4.675	3.38

Source: Brazil 2010 National Census Extended Questionnaire Sample (IBGE, IPUMS-International, 2014). Authors' calculations.

Table 2: Household features

Variable	Sample 6-15 years			Sample 6-18 years		
	Obs.	Mean	Std. Dev	Obs.	Mean	Std. Dev
Living in a rural household	1727270	0.267	0.442	2257010	0.263	0.44
Living in a household connected to the piped water	1722163	0.834	0.372	2250060	0.838	0.368
Living in a household connected to the sewerage	1623076	0.402	0.49	2125039	0.406	0.491
Living in a household where trash is directly collected from	1722163	0.678	0.467	2250060	0.682	0.466
Living in a home without bathrooms	1722163	0.13	0.336	2250060	0.126	0.332
Living in a household that reported a death last year	1725412	0.016	0.127	2254167	0.017	0.129
Living in a dwelling with electricity	1722163	0.974	0.158	2250060	0.975	0.155
Family size	1722163	5	2	2250060	4.95	2.03
Male head of the household	1722163	43.16		1722163	44.13	
Head of Household's schooling (years)	1726334	6.454	4.382	2255352	6.447	4.39
Spouse's schooling (years)	1352952	6.774	4.319	1741918	6.739	4.323

Source: Brazil 2010 National Census Extended Questionnaire Sample (IBGE, IPUMS-International, 2014). Authors' calculations.

Table 3: Features of the water systems

Variable	Observations	Mean	Std. Dev.
Semiarid municipality	5,540	0.204	0.403
Municipal government owned	5,540	0.27	0.444
State government owned	5,540	0.694	0.461
Privately owned	5,540	0.036	0.186
Surface water-sourced	5,516	0.576	0.494
Groundwater-sourced	5,517	0.424	0.494
Integrated water system	5,540	0.132	0.339
Isolated water system	5,540	0.868	0.339
Both systems	5,540	0.027	0.162
Water system is satisfactory	5,525	0.453	0.498
Water system requires new source	5,525	0.085	0.28
Water system needs enlargement	5,525	0.461	0.499
Number of rivers per municipality	5,547	40.447	120.493

Source: ANA Brazil Water Atlas and IBGE Systematic Mapping

Table 4: Table of correlations coefficients of relevant variables

Variable	Sample 6-15 years						
	Connection to piped water (AI)	Connection to Sewerage (AI)	Connection to piped water (PC)	Connection to Sewerage (PC)	Connection to piped water	Connection to sewerage	Years of education
Connection to piped water (AI)	1						
Connection to Sewerage (AI)	0.8323	1					
Connection to piped water (PC)	0.9903	0.7784	1				
Connection to Sewerage (PC)	0.8836	0.8711	0.8935	1			
Connection to piped water	0.4983	0.4189	0.4927	0.4424	1		
Connection to Sewerage	0.2693	0.3236	0.2519	0.2819	0.2681	1	
Years of education	0.0786	0.0652	0.0752	0.0597	0.0725	0.0575	1
Variable	Sample 6-18 years						
	Connection to piped water (AI)	Connection to Sewerage (AI)	Connection to piped water (PC)	Connection to Sewerage (PC)	Connection to piped water	Connection to Sewerage	Years of education
Connection to piped water (AI)	1						
Connection to Sewerage (AI)	0.8273	1					
Connection to piped water (PC)	0.9903	0.7724	1				
Connection to Sewerage (PC)	0.8805	0.8676	0.8903	1			
Connection to piped water	0.4955	0.414	0.4899	0.4382	1		
Connection to Sewerage	0.2661	0.3216	0.2484	0.279	0.2657	1	
Years of education	0.0867	0.071	0.0833	0.0662	0.0811	0.0704	1

Source: Brazil 2010 National Census Extended Questionnaire Sample (IBGE, IPUMS-International, 2014). Authors' calculations. AI: All Instruments. PC: Principal Component.

Table 5: T-tests on means by groups defined through connection to systems

Variable	Sample 6-15 years			
	No connection	Connection	T-Statistic	Statistically different
Water system	2.922323	3.654084	-1.3e+02	Yes
Sewerage system	3.476032	3.748297	-62.7417	Yes
	Sample 6-18 years			
Variable	No connection	Connection	T-Statistic	Statistically different
Water system	3.819925	4.84164	-1.7e+02	Yes
Sewerage system	4.571529	5.002307	-91.1396	Yes

Source: Brazil 2010 National Census Extended Questionnaire Sample (IBGE, IPUMS-International, 2014). Authors' calculations.

Table 6: Effect of connection to piped water on completed years of education

Panel	First stage	Method	Sample		
			6-10 years	6-15 years	6-18 years
A	No first stage	No fixed effects	0.104 (0.017)***	0.374 (0.022)***	0.477 (0.027)***
		Using fixed effects	0.094 (0.006)***	0.269 (0.009)***	0.342 (0.011)***
B	Linear first stage	All instruments	0.216 (0.011)***	0.576 (0.016)***	0.711 (0.018)***
		Principal component	0.21 (0.011)***	0.562 (0.016)***	0.694 (0.018)***
C	Logit first stage	All instruments	0.216 (0.011)***	0.576 (0.016)***	0.71 (0.018)***
		Principal component	0.213 (0.011)***	0.567 (0.016)***	0.701 (0.018)***
D	Censored linear instrument	All instruments		0.131 (0.017)***	0.167 (0.022)***
		Principal component		-0.041 (0.007)***	-0.058 (0.008)***

Notes:* significant at 10 percent level,** significant at 5 percent level,*** significant at 1 percent level. Errors clustered at the municipal level. Number of clusters 4,500. Sample 6-10: 790,167 observations. Sample 6-15: 1,640,274 observations. Sample 6-18: 2,080,737 observations. Standard errors in parenthesis.

Table 7: Effect of connection to sewerage system on completed years of education

Panel	First stage	Method	Sample		
			6-10 years	6-15 years	6-18 years
A	No first stage	No fixed effects	-0.017 (0.015)	0.072 (0.021)***	0.105 (0.024)***
		Using fixed effects	0.009 (0.005)**	0.039 (0.008)***	0.065 (0.010)***
B	Linear first stage	All instruments	0.283 (0.018)***	0.781 (0.025)***	0.957 (0.029)***
		Principal component	0.254 (0.016)***	0.7 (0.023)***	0.857 (0.026)***
C	Logit first stage	All instruments	0.24 (0.016)***	0.68 (0.022)***	0.837 (0.025)***
		Principal component	0.233 (0.015)***	0.654 (0.021)***	0.804 (0.023)***
D	Censored linear instrument	All instruments		0.078 (0.022)***	0.103 (0.027)***
		Principal component		0.014 (0.011)	0.013 (0.014)

Notes:* significant at 10 percent level,** significant at 5 percent level,*** significant at 1 percent level. Errors clustered at the municipal level. Number of clusters 4,500. Sample 6-10: 790,167 observations. Sample 6-15: 1,640,274 observations. Sample 6-18: 2,080,737 observations. Standard errors in parenthesis.

Table 8: Effect of connection to piped and sewerage systems on completed years of education

Panel	First stage	Method	Sample		
			6-10 years	6-15 years	6-18 years
A	No instruments	No fixed effects	-0.013 (0.015)	0.079 (0.021)***	0.115 (0.024)***
		Using fixed effects	0.014 (0.005)***	0.046 (0.009)***	0.075 (0.010)***
B	Linear first stage	All instruments	0.28 (0.018)***	0.775 (0.025)***	0.95 (0.028)***
		Principal component	0.251 (0.016)***	0.695 (0.023)***	0.851 (0.026)***
C	Logit First Stage	All instruments	0.235 (0.015)***	0.668 (0.021)***	0.822 (0.025)***
		Principal component	0.229 (0.015)***	0.646 (0.020)***	0.794 (0.023)***

Notes:* significant at 10 percent level,** significant at 5 percent level,*** significant at 1 percent level. Errors clustered at the municipal level. Number of clusters 4,500. Sample 6-10: 790,167 observations. Sample 6-15: 1,640,274 observations. Sample 6-18: 2,080,737 observations. Standard errors in parenthesis.