**Title**
Impact of access to water and sanitation services on educational attainment



**Authors**
Ortiz-Correa, Javier Santiago
Filho, Moises Resende
Dinar, Ariel

**Publication Date**
2016-04-01

**DOI**
10.1016/j.wre.2015.11.002

Water Resources and Economics ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Water Resources and Economics

journal homepage: www.elsevier.com/locate/wre

# Impact of access to water and sanitation services on educational attainment

Javier Santiago Ortiz-Correa [a,*,1], Moises Resende Filho [a], Ariel Dinar [b]

[a] Universidade de Brasília, Brazil
[b] School of Public Policy, University of California, Riverside, USA

A R T I C L E I N F O

*Article history:*
Received 11 December 2014
Received in revised form
17 November 2015
Accepted 23 November 2015

*Keywords:*
Water
Sanitation services
Education
Brazil

A B S T R A C T

Children are prone to the contagion of waterborne diseases without adequate water and sanitation services. When not sick, children and their caregivers without proper access to such services 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. This paper proposes a household utility maximization model in which access and sanitation services determine the child's health, which in turn affects the child's education and the household welfare. Comparative statics indicate that households consider the health gains to the market value of their leisure time, and the changes in the consumption of other goods. The model is applied to data from Brazil. In order to sort out the endogeneity between provision of water and sanitation services, and educational attainment, the paper uses an instrumental approach, based on the technical features of the water systems and an instrument that measures a proxy of water availability 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.



## 1. Introduction

The UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water GLAAS [44] indicates that 2.5 billion people do not have access to improved sanitation and around 1 billion people are forced to practice open defecation in 90% of the rural areas. Moreover, access to safe drinking water is not a reality for 748 million people around the globe, and 1.8 billion people are at risk of using a water source that can be faecally contaminated. The World Health Organization estimates that every $1 invested in better access to water and sanitation can represent returns ranging from $4 to $12. In addition to the economic returns of these investments, the access to such services is essential for the realization of human rights for all [44–46]. These figures reveal the global impact of the problems associated with the access and the provision to water and sanitation services. They also highlight the relevance of studying how they can become an obstacle for development, and identify the possible policies to overcome them.

Inequality in access to water and sanitation may translate into inequalities in health and education. When not connected to water and sewerage system, household

* Corresponding author.
*E-mail address:* javier.ortiz@email.ucr.edu (J. Santiago Ortiz-Correa).

[1] A CNPq postdoctoral grant is greatly acknowledged. We thank Luzia Freitas and Renato Lelis at IBGE-Brasilia for granting access to the systematic mapping data. And to Todd Sorensen at the University of Nevada, Reno, for allowing us to use his server for statistical and econometric procedures.

http://dx.doi.org/10.1016/j.wre.2015.11.002
2212-4284/© 2015 Elsevier B.V. All rights reserved.

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 collecting, hauling, and taking care of water and sewerage storage than attending school or preparing homework. Without proper water and sanitation services, adequate hygiene is not maintained, which, in turn, increases the likelihood of contracting diseases.

Academic performance in school 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) [25]. Thus, better water and sanitation services help households save on healthcare and improve productivity. Second, studies have found that dehydration may harm cognitive discrimination and short-term memory [30]. As a consequence, lack of water impairs children's academic performance by reducing their cognitive capacity.

The goal of this paper is to explore how access to water and sanitation services affects school attainment, measured by the completed school years[2]. The theoretical model that will be developed in the paper is applied to data from Brazil, a country marred by inequalities [24]. In terms of water, the economically prosperous southeastern and southern regions fare better in the provision of access to water and sanitation services than the poorer regions of the country. For Brazil, the study of access to water and sanitation services is relevant, mainly because of the inequalities across the country. The poor semi-arid 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 arises from an international and sustainability perspective. Impacts from global warming on water availability will force policy-makers 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.

As its first contribution, this paper explores how non-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 of services will result in healthier households and more time available to achieve higher levels of education. Tackling endogeneity and simultaneity in the study of access to water and educational achievement is the second contribution. 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 of the paper is it offering of a theoretical household utility maximization model relating access to water and sanitation services to health and education.

Results indicate that there is a positive effect of access to water and sanitation services on the number of completed school years using data from 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 compared to those that do not enjoy such amenities. This time-related trajectory 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.

## 2. Literature review[3]

### 2.1. The benefits of access to water and sanitation services

Access to water and sanitation services was defined as a human right by the [46] (Resolution 64/292; [44,45] the United Nations General Assembly). The human rights perspective obliges governments to act in a positive and proactive way, for instance, by expanding coverage [3]. 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 [26]. The time available for livelihood activities increases as the incidence of diarrhea falls [10].

There are three main challenges in improving the access and quality of water and sanitation services: first, the significant investments in operation and maintenance; second, lack of governance policies promoting private sector involvement; and, third, difficulties in setting appropriate pricing structures [39,9]. 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 [4]. Access to credit, and not the costs, is the real obstacle to improve households' access to higher-quality water [16,17].

[2] The Brazilian Sanitation Act (Federal Law 11.445/2007) states that sanitation services are composed of 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.

[3] For a full discussion of the literature review, theoretical model and empirical strategy, the reader is advised to review the Working Paper version available at: http://goo.gl/Onvykq

### 2.2. 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 [35]. Governments invest in water and sanitation services infrastructure, aiming at achieving full coverage, mainly because of the effects on health: healthier children perform better in school; healthy adults are more productive at work and can take better care of their offsprings; health improves the capital base of the society, because healthy people can save more for retirement; healthy societies have more dynamic economies, because the ratio of workers to dependents increases; and, finally, healthier societies attract more investment and tourism [8].

Better hygiene and safer excreta disposal have a bigger impact on health than improved drinking water alone [1]. Nevertheless, the desire to feel and smell clean and to follow social norms may be more effective in changing hygienic behaviors than health considerations [20]. One of the variables that is most affected by better access to water and sanitation services is child mortality. In urban areas, access to potable water and sewerage connections does reduce child mortality [43]. If not mortality, water is related to high levels of morbidity due to the incidence of diarrhea and especially severe diarrhea. A severe case of diarrhea is defined by three or more watery or loose stools during a 24 h period (WHO 2004).

### 2.3. The mechanisms of time use and mothers' outcomes

Households may have more time available to engage in income-generating activities with enhanced access to water and sanitation services [38]. Better access to water not only increases the productivity of households' labor through health gains, but it also results in reduced communicable diseases within communities. Time availability for income-generating activities and education has a clear and strong gender bias [40,41]. In many societies, women and girls carry out the housekeeping and water collection, transportation, storage, and handling activities. Breaking the cycle of poverty for women, through access to water, may end up in better outcomes for their children. Women's work increases financial independence and their bargaining power within the household, which results in improved child welfare [31].

When water is not available within the household premises, the distance to the water source becomes a critical variable for children's health and development. 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 [36,37].

### 2.4. The Brazilian context of water, sanitation, health and education

#### 2.4.1. Institutional framework of access to water and sanitation in Brazil

The lack of a well-functioning institutional framework in Brazil is paramount. Setting up the regulatory framework for sanitation services is a challenge since the sector exhibits natural monopolies, low technological dynamism, different degrees of technology adoption, and movement toward the productive frontier [13] (Galvao Junior 2009). All of these reasons lead to differences in service provision. Differences in access to public services at the local level, theoretically, should arise from local differences in the valuation of and in the provision costs of the services [27]. However, access to water and sanitation is intertwined with some well-known income and educational inequalities at the regional level [39].

The National Water Agency (ANA) estimates that the total capacity of water systems is around 587 $m^3$/s, and the maximum current demand is around 543 $m^3$/s. By 2015, it is expected that 55% of the Brazilian 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 estimated that the investments in existing water systems and the use of new water sources will amount to US$11 billion up to 2025. In addition, US$22 billion will need to be invested in the sanitary systems of the municipalities with water quality problems [2].

#### 2.4.2. 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 [21]. In 1997, Brazil faced the infant mortality rate of 31.9 dead children (per 1000 live births), which went to 13 dead children (per 1000 live births) in 2012 [46]. The reduction in the infant mortality rate at the municipal level, between 1980 and 2000, was mainly explained by growth in income, reduced illiteracy of women, and adolescent fertility rates, as well as more private health care and basic public services [6]. Government health programs, like Family Health Program, and, at a lower magnitude, improving access to water and sanitation services contributed to reduce the burden of child and infant mortality throughout the country [34]. Improved access could have prevented nearly 40% of the diarrhea-related diseases [35].

The Brazilian expansion of access to water and sanitation services has been uneven when comparing water to sanitation in urban and rural areas (IBGE 2014). Access to water in urban areas is around 90%, but access to sanitation services (connection to sewerage system) is only 60%. The situation is grim for rural areas, where connection rates are much lower.

In a study of diarrhea incidence in the city of Salvador [35], researchers found that the incidence of diarrhea was lower in the groups with access to both sewerage and drainage. Another study in Salvador [5] argues that 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 non-random placement as water systems are usually built in regions with better health infrastructure [22]. 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 at the municipality level [12].

### 2.4.3. Enrollment determinants in Brazil

Health gains have come at the same time as improvements in education enrollment throughout Brazil. Education figures show that educational achievement is improving. The percentage of people completing 11 or more years of school has been growing steadily since 2000, and it is now around 35% (IBGE 201). The Brazilian education system has made real progress in enrolling all children, up to the age of 14 years (IBGE 2014). Dropping out of school is a serious problem for children 15 years and older [42].

In Brazil, early parenthood and extreme poverty increase the probability of dropping out of school [11]. Household income and the labor status of the head of the household also determine children's enrollment [14,18]. Paradoxically, positive income shocks can also be detrimental for academic performance and attainment [32,33]. Birth order is another variable defining how parents allocate resources for education among their children [19]. However, the decision to stay in school and to advance to college education may, ultimately, depend on the returns to education [7].

## 3. Theoretical model

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 [28,29], which is also used in a propensity score matching application [31]. In association with the originally proposed model, the children's health production function in this paper is included in the parental utility function. Notwithstanding, the model proposed below 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. Four, it also states that households have to pay for education of their children. And five, is assumes that households do not value directly their expenditure on health; they only value it through the education achievement of their children.

### 3.1. The maximization problem

Households maximize a continuous double differential utility $U(.)$, of children's education ($D$), the level of consumption of 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 ($l(q_{ws})$, with $l_{q_{ws}} > 0$, $l_{q_{ws}q_{ws}} < 0$,). Thus, the utility function is represented by:

$$U\left(D(h), X, l(q_{ws})\right) \tag{1}$$

It is further assumed that 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. A priori, $q_{ws}$ indicates the type of services the household gets and, therefore, the quality of the water it consumes and the sanitary services it uses. $q_{ws}$ also 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:

$$h(q_{ws}, e) \tag{2}$$

Households act as price (or fee) takers in all markets. 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 sanitation services ($c$). Households divide their total available time (here, 1 unit of total time), between leisure ($l$) and labor ($L$), such that $L + l = 1$. When working in the labor market, households are paid a wage rate ($r$). Besides their income from work, households are endowed with a monetary bundle (e.g. savings, independent from work) ($M$). Therefore, the household's budget constraint is:

$$M + r\left(1 - l(q_{ws})\right) = xp_x + p_D + e + cq_{ws} \tag{3}$$

And thus, the household's maximization problem is:

$$\underset{e,\, x,\, l,\, q_{ws}}{Max}\; U\left(D(h), X, l\left(q_{ws}\right)\right) s.\,t.\; M + r\left(1 - l\left(q_{ws}\right)\right) = xp_x + p_D + e + cq_{ws} \tag{4}$$

### 3.2. The comparative statics

After setting up the Lagrange, the first and second order conditions for a maximum are derived.

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

$$\frac{h_{q_{ws}}}{h_e} - c < rl_{q_{ws}} - \left(\frac{U_{lx}}{U_{Dx}}\right)\left(\frac{l_{q_{ws}}}{D_h h_e}\right) \text{Condition1}$$

The left hand side terms can be jointly interpreted as the net gain in children's health. It consists of the ratio between children's health improvement from the sanitary services and gains from the health-related expenditure, minus the cost of access to water and sanitary services. The right hand side is composed of two terms. The first term is the benefits from leisure time gained from improvements in water and sanitary services (valued at the wage rate, $rl_{q_{ws}}$). The second term is the ratio of improvements in leisure to education from variations of the quantity of the composite good ($\frac{U_{lx}}{U_{Dx}}$) multiplied by 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 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.

As for the comparative statics, only two effects are 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 to reduce the risk of sickness of their children. For this relationship to exist, the following condition has to hold:

$$rl_{q_{ws}} - \left(\frac{U_{xl}}{U_{xD}}\right)\left(\frac{l_{q_{ws}}}{D_h h_e}\right) > \frac{h_{q_{ws}}}{h_e} - c \text{ Condition2}$$

Condition 2 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 change, expenditure on education and on health change accordingly and, in the process, impact the amount the household spends on the composite good. Under this condition, the focus is on how the utility of the consumption of the composite good is affected. 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, 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:

$$q_{ws}\left[\left(\frac{U_{Dx}}{U_{xD}}\right)\left(\frac{h_{q_{ws}}}{h_e}\right)+\left(\frac{U_{lx}}{U_{xD}}\right)\left(\frac{l_{q_{ws}}}{D_h h_e}\right)\right]>0 \text{ Condition3}$$

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 consumed 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 water and sanitation services. They can either haul water from a river or well, use latrines, or even share a water connection with other households.

Another interesting point about Condition 3 has to do with the cross derivatives. The cross derivatives between education and the composite good are amplified by the ratio of changes in health from access to water and sanitation services, and from health expenditure, ($\frac{U_{Dx}}{U_{xD}}$)($\frac{h_{q_{ws}}}{h_e}$). 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 of the 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, ($\frac{U_{lx}}{U_{xD}}$)($\frac{l_{q_{ws}}}{D_h h_e}$). The relevant point is that changes in health are directly related to the changes in education and the consumption level of the composite good. Nevertheless, the changes in education have to relate to leisure. This suggests that health and leisure are intertwined in the education decision at the household level.

### 3.3. The hypothesis

Based on the results of the theoretical model and on findings in the cited references, the following hypotheses will be tested in the empirical application:

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

**Table 1**
Individual level characteristics.
*Source:* Brazil 2010 National Census Extended Questionnaire Sample (IBGE, IPUMS-International, 2014). Authors' calculations.

| 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 | 0.250 | 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 | 0.310 | 2257010 | 0.912 | 0.283 |
| Schooling (years) | 1727270 | 3.532 | 2.703 | 2257010 | 4.675 | 3.380 |

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

**Hypothesis 3.** The oldest child in the household 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.

## 4. Data sources

The empirical test of the hypotheses is conducted using the Brazilian Extended Questionnaire Census Sample 2010. This dataset is supplemented by data on water systems, and a variable measuring water availability—the number of rivers within the municipal jurisdiction. The main sources for the data are the Brazilian Institute of Geography and Statistics (IBGE), and the Water National Agency (ANA). The file of the Extended Questionnaire Census Sample was obtained from the University of Minnesota's Population Center IPUMS-International project.

### 4.1. Individual and Household data

The variables of interest for our analysis are related to education, age, gender and position in the household (Table 1). Educational achievement is measured as the number of completed school years. It is likely that the education variable suffers from measurement error that may attenuate the estimates. The error could result from the fact that 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. 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 of the decision-maker in the household. It is preferred over the schooling of the father and mother in order to take into account different family structures.

The model is a static, one-period model. It is true 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. Three age ranges of the children are observed and studied: from 6 to 10 years, from 6 to 15 years of age, and from 6 to 18 years of age. Using these samples aims at identifying the effect that accrues over time and the possible diminishing marginal returns. In other words, this is an indirect approach, lacking other information, in order to disentangle the accumulated and instantaneous effect of access to water and sanitation services. 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. 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.

Household data (Table 2) allows 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.

### 4.2. Water systems data

Water system data (Table 3) is recorded at the municipal level. The National Water Agency conducts a yearly assessment of the water systems at the municipal level (Atlas) that compiles all relevant information on water provision. The variables used in the assessment signal water availability at the municipal level and, consequently, the difficulty of the households to obtain better access to water and sanitation services. On average, it is assumed that households within municipalities that have groundwater systems often face difficulty in getting access to water and sanitation

**Table 2**
Household features.Source: Brazil 2010 National Census Extended Questionnaire Sample (IBGE, IPUMS-International, 2014). Authors' calculations.

| 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 | 0.440 |
| 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 | 0.130 | 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 | 0.43 | 0.385 | 1722163 | 0.44 | 0.392 |
| Head of Household's schooling (years) | 1726334 | 6.454 | 4.382 | 2255352 | 6.447 | 4.390 |
| Spouse's schooling (years) | 1352952 | 6.774 | 4.319 | 1741918 | 6.739 | 4.323 |

**Table 3**
Features of the water systems.
*Source:* ANA Brazil Water Atlas and IBGE Systematic Mapping

| 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 | 0.280 |
| Water system needs expansion | 5.525 | 0.461 | 0.499 |
| Number of rivers per municipality | 5.547 | 40.447 | 120.493 |

services. The reason is that those systems might be more expensive to operate, due to the cost of electricity for pumping water. Water scarcity and other difficulties of access are also expected in municipalities in which water systems need to be expanded. Isolated water systems (defined as the systems that only serve one municipality) can be more beneficial for municipalities because they do not have to share water resources with other municipalities. However, integrated water systems (that serve two or more municipalities) can also be beneficial, because operation costs can be shared by several municipalities, and integrated water systems are more cost-effective 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[4]. 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 household 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.

## 5. Empirical strategy

### *5.1. 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. Observed and unobserved factors can cause 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). Access to water and sanitation is not randomly assigned. Water systems investments are not undertaken randomly across municipalities. Moreover, the water 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. Household income plays a role too, but here it is assumed that it is the endogeneity at the municipality level that has a bigger weight than the possible impact of household income over the decision to connect to the system. Thus, endogeneity bias is explained by simultaneity and omitted variable bias.

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 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. This approach is similar to the approach in a paper exploring the relationship between access to water and mothers' outcomes [31], where the authors assumed that when relevant characteristics influencing infrastructure and outcomes were controlled by their geographical variables and, therefore, infrastructure placement is random.

### *5.2. Identification strategy*

The identification strategy relies on the household municipality of residence. That municipality of residence is used to instrument the connection to the piped water system and the sewerage system at the household level. As a reminder, the regressions are carried out at the individual child level 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 decision of the household. In that respect, the location might be taken as exogenous to the childrens' performance, as well as the availability of piped water, and sewerage systems. As it can be seen, there are statistically significant differences ($t$-test) 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 4),

The main weakness of the identification strategy is related to household migration across municipalities and across states. If this happens, and assuming that access to water, sanitation, and education is a main driver of household migration, the sample will not be

[4] 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.

**Table 4**
*t*-tests on means by groups defined through connection to systems. *Source:* Brazil 2010 National Census Extended Questionnaire Sample (IBGE, IPUMS-International, 2014). Authors' calculations.

| 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 |
| Variable | Sample 6–18 years | | | |
| | 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 |

representative. Any estimator would be biased upwards, because the sample is composed of people living in municipalities with better provision of water and sanitation services (and education too). This threat is controlled by including a variable measuring the time the household has resided 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. 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 enormous 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 not operating 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. This also pulls the estimates towards zero.

The sanitary conditions at school are also important for children's health and 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. What happens to the educational performance of children that have good water and sanitation services at home, but do not have them at school? Based on the theoretical model (Section 3), households would be forced to spend more on health-related items or services in order to overcome any possible negative impact on their children of the sanitary conditions at school.

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. Instead, a variable is included to control for the death of any family member during the last year, to take into account some sort of family's vulnerability to economic shocks due to the death of a member.

### 5.3. Estimated equation

The equation used to carry out the estimation is:

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

Where, $Education_{ihm}$ is the level of education achievement (years of 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 child. $\Lambda_{ihm}$ is a matrix which contains 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. $\Pi_{hm}$ is a matrix which includes 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. $\beta_1$ is an estimated coefficient, $\beta_2$ and $\beta_3$ are vectors of estimated coefficients. $\theta_m$ is the municipality fixed effect. And $\varepsilon_{ihm}$ is a random disturbance.

Household fixed-effects cannot be used, because 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.

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 household, 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:

$$Access_{ihm} = \alpha_0 + \alpha_1 Ground\ \ Water_{hm} + \alpha_2 Isolated_{hm} + \alpha_3 Expansion_{hm} + \alpha_4 Rivers_{hm} + \alpha_5 Owned\ \ Home_{ihm} + \alpha_6 Electricity_{ihm} + \alpha_7 Bathroom_{ihm} + \nu_{ihm} \quad (6)$$

$Ground\ \ Water_{hm}$ 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 jurisdiction. 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, $Bathroom_{ihm}$ takes into account the existence of a bathroom within the dwellings (value of 1 and zero otherwise).

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 not asymptotically robust to non-spherical errors and the null hypothesis, that the coefficients are conjointly equal to zero, will not be correctly tested.

The interpretation will focus on $\beta_1$, the coefficient of the variable indicating the access to the services at the household. Its estimate 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. $\beta_1$ estimate is also a total average affect. It is a total effect because, by the assumptions presented in the model, it estimates 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. 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 averaged at the municipal level, due to the use of the municipality-level fixed effect.

## 6. Results

Tables 5 and 6 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). Full table of regressions are available upon request. The use of the instrumental access measures (Eq. (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 the estimated instrumented access was less than the median of that variable distribution, then 0 is assigned (and 1 if above the median of that variable). This is a way to explore the situation when only 50% of households have access to either service. Another robustness check is conducted by a Principal Components analysis of the variables describing the water system in the First stage regression instrumenting for access (KMO stat for the Principal Components analysis is equal to or bigger than 0.6). Overall, results of the second stage regression can be read in terms of years of education.

Some words about the control variables are worth mentioning. The variable for gender indicates a bias in

**Table 5**
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<br>(0.017)*** | 0.374<br>(0.022)*** | 0.477<br>(0.027)*** |
| | | Using fixed effects | 0.094<br>(0.006)*** | 0.269<br>(0.009)*** | 0.342<br>(0.011)*** |
| B | Linear first stage | All instruments | 0.216<br>(0.011)*** | 0.576<br>(0.016)*** | 0.711<br>(0.018)*** |
| | | Principal component | 0.21<br>(0.011)*** | 0.562<br>(0.016)*** | 0.694<br>(0.018)*** |
| C | Logit first stage | All instruments | 0.216<br>(0.011)*** | 0.576<br>(0.016)*** | 0.71<br>(0.018)*** |
| | | Principal component | 0.213<br>(0.011)*** | 0.567<br>(0.016)*** | 0.701<br>(0.018)*** |
| D | Censored linear instrument | All instruments | | 0.131<br>(0.017)*** | 0.167<br>(0.022)*** |
| | | Principal component | | −0.041<br>(0.007)*** | −0.058<br>(0.008)*** |

*Significant at 10% level, **significant at 5% level.
*** Significant at 1% level. Errors clustered at the municipal level. Number of clusters 4500. 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 6**
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 | 0.072 | 0.105 |
| | | | (0.015) | (0.021)*** | (0.024)*** |
| | | Using fixed effects | 0.009 | 0.039 | 0.065 |
| | | | (0.005)** | (0.008)*** | (0.010)*** |
| B | Linear first stage | All instruments | 0.283 | 0.781 | 0.957 |
| | | | (0.018)*** | (0.025)*** | (0.029)*** |
| | | Principal component | 0.254 | 0.7 | 0.857 |
| | | | (0.016)*** | (0.023)*** | (0.026)*** |
| C | Logit first stage | All instruments | 0.24 | 0.68 | 0.837 |
| | | | (0.016)*** | (0.022)*** | (0.025)*** |
| | | Principal component | 0.233 | 0.654 | 0.804 |
| | | | (0.015)*** | (0.021)*** | (0.023)*** |
| D | Censored linear instrument | All instruments | | 0.078 | 0.103 |
| | | | | (0.022)*** | (0.027)*** |
| | | Principal component | | 0.014 | 0.013 |
| | | | | (0.011) | (0.014) |

*Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level. Errors clustered at the municipal level. Number of clusters 4500. Sample 6–10: 790,167 observations. Sample 6–15: 1,640,274 observations. Sample 6–18: 2,080,737 observations. Standard errors in parenthesis.

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). 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 residing always in the same municipality. The variable controlling for the occurrence of a death within the household shows a negative, yet small, impact on the number of completed school years. Finally, children residing in rural areas have almost 0.12 less school years than those in urban areas.

### 6.1. *Impact of access measures without instruments*

This coefficient demonstrates 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 5), the impact of access to water ranges 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 5) the point estimates are subtly reduced to 0.094 (6–10 years sample) and 0.342 (6–18 years sample), respectively. 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 6). Without fixed effects or 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.

### 6.2. *Impact of access measures using a linear probability model instrumental first stage*

Panel B, of both Tables 5 and 6, 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 [31]. Also, contact with excreta can be more harmful for children in transmitting diseases. The burden of the diarrhea diseases on children's health and on the family leisure time can lead to reduced performance at school. Effects seem to have a positive relationship with the age of children, pointing at accumulated effect that was discussed earlier. The impact seems to have diminishing marginal returns with age, increasing 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 variable. Ignoring endogeneity leads to a severely underestimated impact of access to water, but even more, the impact of the access to sanitation services.

### 6.3. *Impact of access measures using a logit instrumental first stage*

Panel C of Tables 5 and 6 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 water system remain almost the same. Estimates also exhibit the diminishing marginal returns of schooling as children get older. 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 better healthy status throughout school life, and more time available for leisure (and, certainly, studying out of school), 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.

### 6.4. *Impact of access measures using a censored transformed logit instrumental first stage*

These regressions (Panel D of Tables 5 and 6) are the empirical verification 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 increases, while the effect of the connection to the sewerage system decreases. The expectation is not met in terms of access to water because, actually, the point estimates get smaller. Expectations do materialize for connection to the sewerage system as the point estimates get smaller and only top a 0.1 additional school year (or 20 school days) for the 6–18 years sample.

### 6.5. *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). About 39% of children in the sample live in households connected to both services. Point estimates are presented in Table 7. Panel A shows, again, how pervasive endogenity 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 since the point estimates have relatively smaller standard errors. It may seem that the joint 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.

## 7. Conclusions

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 expected 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 female children.

This paper estimates the impact of access to water and sanitation services on education attainment, measured as completed years of education. The results imply that children living in a household connected to a piped water system are endowed with 0.7 more school years, and that children connected to the sewerage have an additional of 0.8 school years compared to those children living in households lacking these services. Results reveal that the educational achievement of the head of the household matters in the schooling of children. More importantly,

**Table 7**
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<br>(0.015) | 0.079<br>(0.021)*** | 0.115<br>(0.024)*** |
| | | Using fixed effects | 0.014<br>(0.005)*** | 0.046<br>(0.009)*** | 0.075<br>(0.010)*** |
| B | Linear first stage | All instruments | 0.28<br>(0.018)*** | 0.775<br>(0.025)*** | 0.95<br>(0.028)*** |
| | | Principal component | 0.251<br>(0.016)*** | 0.695<br>(0.023)*** | 0.851<br>(0.026)*** |
| C | Logit First Stage | All instruments | 0.235<br>(0.015)*** | 0.668<br>(0.021)*** | 0.822<br>(0.025)*** |
| | | Principal component | 0.229<br>(0.015)*** | 0.646<br>(0.020)*** | 0.794<br>(0.023)*** |

*Significant at 10% level, **significant at 5% level.
*** Significant at 1% level. Errors clustered at the municipal level. Number of clusters 4500. Sample 6–10: 790,167 observations. Sample 6–15: 1,640,274 observations. Sample 6–18: 2,080,737 observations. Standard errors in parenthesis.

results confirm typical sources of discrimination in terms of 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 vulnerability to and economic shocks due to the death of a household member. 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 discussed

The immediate effect of poor access to water and sanitation is either failure to complete high school or failure to obtain higher education. Assuming a working life span of 40 years, de Holanda Barbosa Filho and Pessôa [15] estimated that the wage premium of completing 11 years of school was 34.3% (when compared to those with lower educational attainment) 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 the benefits of schooling, which will result in a lower net wage premium and a lower IRR.

Estimates provide evidence for accepting Hypothesis 1, namely that access to water and sanitation services improves schooling attainment. 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 that of access to drinking 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. Hypothesis 4 has to be rejected; female children, regardless of their access to water and sanitation services, attained higher schooling levels than male children. Hypothesis 5 is accepted as 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 [23]. 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 [21]. Coverage at the household level needs to be intertwined with coverage at the schools.

## Acknowledgements

A CNPq (Grant no. 150437/2013-7) postdoctoral Grant is greatly acknowledged. We thank Luzia Freitas and Renato Lelis at IBGE-Brasilia for granting access to the systematic mapping data. And to Todd Sorensen at the University of Nevada, Reno, for allowing us to use his server for statistical and econometric procedures.

## References

[1] A.E. Aiello, E.L. Larson, What is the evidence for a causal link between hygiene and infections? Lancet Infect. Dis. No. 2 (2002) 103–110.
[2] Agencia Nacional de Agua, Atlas Brasil Abastecimiento urbano de Agua, Panorama Nacional. Agencia Nacional de Agua, Superintendencia de Planejamento de Recursos Hidricos, Brasília, Brazil, 2011, pp. 72.
[3] P.B. Anand, Right to water and access to water: an assessment, J. Int. Dev. 19 (2007) 511–526.
[4] P. Bajpai, L. Bhandari, Ensuring access to water in urban households, Econ. Polit. Wkly. 36 (39) (2001) 3774–3778.
[5] M. Barreto, B. Genser, A. Strina, M. Teixeira, A.M. O Assis, R. Rego, C. Teles, M. Prado, S. Matos, D. Santos, L. dos Santos, S. Cairncross, Effect of city-wide sanitation programme on reduction in rate of childhood diarrhoea in northeast Brazil: Assessment by two cohort studies, Lancet 370 (2007) 1622–1628.
[6] A.M. Barufi, E. Haddad, A. Paez, Infant mortality in Brazil, 1980-2000: a spatial panel data analysis, BMC Public Health 12 (181) (2012) 1–15.
[7] C. Binelli, C. Meghiry, N. Menezes-Filhoz, Education and wages in Brazil, Mimeo (2006) 47.
[8] D.E. Bloom, D. Canning, M. Weston, The value of vaccination, World Econ. 6 (3) (2005) 15–39.
[9] C. Briceño-Garmendia, A. Estache, N. Shafik, Infrastructure services in developing countries: Access, quality, costs and policy reform, World Bank Policy, Res. Work. 3468 (2004) 33.
[10] J. Cameron, P. Jagals, A manual for economic assessment of drinking water interventions, World Health Organization, Geneva, Switzerland, 2012, 43.
[11] A.R. Cardoso, D. Verner, School drop-out and push-out factors in Brazil: The role of early parenthood, child labor, and poverty,IZA Discussion Paper Series No. 2515, 2006, pp. 24.
[12] M.J. Cardoso de Mendonça, R. Seroa da Motta, Saúde e Saneamento no Brasil, Planej. Polít. Públ. 30 (2007) 15–30.
[13] R.S. da Motta, A. Moreira, Efficiency and regulation in the sanitation sector in Brazil, Util. Policy 14 (2006) 185–195.
[14] I.E. de Carvalho Filho, Household income as a determinant of child labor and school enrollment in Brazil: evidence from a social security reform,IMF Working Paper WP/08/241, 2008, pp. 38.
[15] F. de Holanda Barbosa Filho, S. Pessôa, Retorno da educação no Brasil, Pesqui. e Planej. Econ. 38 (1) (2008) 97–126.
[16] F. Devoto, E. Duflo, P. Dupas, W. Pariente, V. Pons, Happiness on tap: Piped water adoption in urban Morocco, Massachusetts Institute of Technology Department of Economics, Working Paper 11-05, 2011, pp. 40.
[17] S. Duryea, D. Lam, D. Levison, Effects of economic shocks on children's employment and schooling in Brazil, J. Dev. Econ. 84 (2007) 188–214.
[18] P. Emerson, A. Portela Souza, Birth order, child labor, and school attendance in Brazil, World Dev. 36 (9) (2008) 1647–1664.
[19] L. Fewtrell, R.B. Kaufmann, D. Kay, W. Enanoria, La Haller, J. M. Colford Jr., Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: A systematic review and meta-analysis, Lancet Infect. Dis. 5 (2005) 42–52.
[20] M. Fontana, G. Zuin, P. Pancheri, F. Fusco, A. Lambertini, R. Berni Canani, Costs associated with outpatient diarrhoea in infants and toddlers: a nationwide study of the Italian Society of Paediatric Gastroenterology and Hepatology (SIGEP), Dig. Liver Dis. 36 (2004) 523–527.
[21] A.C. Galvão Junior, Desafios para a universalização dos serviços de água e esgoto no Brasil, Public Health 25 (6) (2009) 548–556.
[22] S. Gamper-Rabindran, S. Khan, C. Timmins, The impact of piped water provision on infant mortality in Brazil: A quantile panel data approach, J. Dev. Econ. 92 (2010) 188–200.
[23] L. Heller, Acesso aos serviços de abastecimento de água e esgotamento sanitário no Brasil: considerações históricas, conjunturais e prospectivas, University of Oxford Centre for Brazilian Studies, Working Paper Number CBS-73-06, 2006, pp. 59.
[24] C. Herran, Reducing poverty and inequality in Brazil, Economic and Social Study, Inter American Development Bank, 2006, 62 Series RE1-05-002.
[25] G. Hutton, Global Costs And Benefits Of Drinking-water Supply And

Sanitation Interventions To Reach The MDG Target And Universal Coverage, World Health Organization, Geneva, Switzerland, 2012, 67.
[26] M. Ihsan Ajwad, Q. Wodon, Who Benefits From Increased Access To Public Services At The Local Level? A Marginal Benefit Incidence Analysis For Education And Basic Infrastructure, World Bank Economists' Forum, 2002, 155–175.
[27] G.M. Ikeda do Carmo, C. Yen, J. Cortes, A. Araujo Siqueira, W. de Oliveira, J.J. Cortez-Escalante, B. Lopman, B. Flannery, L. de Oliveira, E.H. Carmo, M. Pate, Decline in diarrhea mortality and admissions after routine childhood rotavirus immunization in Brazil: a time-series analysis, Plos Med. 8 (2011) 1–11. 4, e1001024.
[28] J. Jalan, M. Ravallion, Does piped water reduce diarrhoea for children in rural India? J. Econ. 112 (2003) 153–173.
[29] A. Kaushik, M.A. Mullee, T.N. Bryant, C.M. Hill, Association between children's access to drinking water in primary schools and their fluid intake: can water be "cool" in school? Child Care Health Dev. 33 (4) (2007) 409–415.
[30] G. Khanna, The impact on child health from access to water and sanitation and other socioeconomic factors, HEI Working Paper No: 02/2008, 2008, PP. 66.
[31] G. Koolwal, D. Van de Walle, Access to water, women's work and child outcomes, Policy Res. Work. 5302 (2010) 39.
[32] D.I. Kruger, Coffee production effects on child labor and schooling in rural Brazil, J. Dev. Econ. 82 (2007) 448–463.
[33] J. Macinko, F. Guanais, M.F. Marinho de Souza, Evaluation of the impact of the Family Health Program on infant mortality in Brazil, 1990–2002, J. Epidemiol. Community Health 60 (2006) 13–19.
[34] L.R.S. Moraes, J. Azevedo Cancio, S. Cairncross, S. Huttly, Impact of drainage and sewerage on diarrhoea in poor urban areas in Salvador, Brazil, Trans. R. Soc. Trop. Med. Hyg. 97 (2003) 153–158.
[35] M.T. Pepe Razzolini, W.M. Risso Günther, Impactos na saúde das deficiências de acesso a agua, Saúde Soc. 17 (1) (2008) 21–32.
[36] A.J. Pickering, J. Davis, Freshwater availability and water fetching distance affect child health in Sub-Saharan Africa, Environ. Sci. Technol. 46 (2012) 2391–2397.
[37] C. Rakodi, A capital assets framework for analysing household livelihood strategies: implications for policy, Dev. Policy Rev. 17 (1999) 315–342.
[38] L.C. Rangel, M. Griesinger, J.N.W. Dachs, M.A. Bittner, S. Tavares, Inequities in access to and use of drinking water services in Latin America and the Caribbean, Pan Am. J. Public Health 11 (5–6) (2002) 386–396.
[39] A.E. Reymao, B.A. Saber, Acesso à água tratada e insuficiência de renda duas dimensões do problema da pobreza no Nordeste brasileiro sob a óptica dos objetivos de desenvolvimento do milênio, Rev. Iberoam. Econ. Ecol. 12 (2009) 1–15.
[40] J. Roy, B. Crow, Gender relations and access to water: what we want to know about social relations and women's time allocation, UC Santa Cruz Center for Global, International and Regional Studies Working Papers, 2004, pp. 25.
[41] A. Santos, J. Roberts, M. Barreto, S. Cairncross, Demand for sanitation in Salvador, Brazil: a hybrid choice approach, Soc. Sci. Med. 72 (2011) 1325–1332.
[42] S. Schwartzman, Education-oriented social programs in Brazil: the impact of Bolsa Escola, Instituto de Estudos do Trabalho e Sociedade. Presented at Global Conference on Education Research in Developing Countries (Research for Results on Education), Global Development Network, 2005, pp. 28.
[43] A. Shi, How access to urban potable water and sewerage connections affects child mortality, Development Research Group World Bank Mimeo, 2006, 33.
[44] United Nations Organization, Global Analysis and Assessment of Sanitation and Drinking-Water GLAAS, December 1st, 2014. United Nations: ⟨http://goo.gl/PRnFXq⟩.
[45] United Nations Organization, Water, Sanitation and Hygiene, December 1st, 2014. United Nations Organization: ⟨http://goo.gl/b9blXJ⟩.
[46] World Meteorological Organization, Dublin Conference Declaration 1992,January 20, 2014. World Meteorological Organization: ⟨http://goo.gl/TXInV0⟩.