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Sanitation and Health: Empirical evidence for Brazilian Municipalities

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The relationship between sanitation policies (access and quality) and health in Brazilian municipalities was estimated from 2003 to 2010 using a panel data model with corrections for missing data. The results suggest a limited effect of sanitation policy on health. Compared with results from the literature, we found that the worsening quality of water appears to be associated with increased rates of mortality and hospitalization for children up to one month of age. Improvements in sewage sanitation have reduced the mortality and morbidity rates in children aged one to four. Improved access to piped water is associated with decreased hospitalization related to dysentery and acute respiratory infections (ARI) and does not have an effect on child mortality. Finally, epidemiological transition is only supported by weak evidence, including a more intense effect of reduced access to sanitation in municipalities with the worst mortality and morbidity indicators. In most models, this theory has been rejected.

Keywords: Sanitation policies, mortality rates, morbidity indicators, epidemiological transition.

JEL: I1

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1. Introduction

Water and sanitation access indicators are usually established under policies aimed at improving a population's health quality. This association has been extensively studied in countries or communities with low development rates. However, it is unclear whether sanitation policies affect health when the population has a high educational level, clear hygiene concepts or high levels of compliance with sanitation policy.

The aim of this paper is to identity the effects of sanitation policies on health indicators for Brazilian municipalities. Socioeconomic indicators are heterogeneous among Brazilian regions. For example, according to data from the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística - IBGE) in 2013, the average educational level of individuals over 25 in southeast Brazil was 8.4 years of study, whereas the average educational level of the same age group in northeast Brazil was 6.4 years of study. Because of differences among Brazilian regions, the aim is to explore the relevant heterogeneity of developmental stages in Brazilian municipalities to identify the role of water access and quality as well as sewage sanitation on mortality and morbidity indicators.

This is not the first study conducted to identify the relationship between sanitation and health in Brazil; the first was conducted by Merrick (1983). Using data from the 1970 census and National Household Sample Survey (Pesquisa Nacional por Amostra de Domicílios – PNAD) of 1976, Merrick determined that access to water had a positive impact on reducing child mortality, and maternal education was identified as the main variable contributing to reductions in mortality. This result was corroborated by Kassouf (1995). Alves and Belluzzo (2004) and Soares (2007) used data from the censuses for Brazilian municipalities between 1970 and 2000 and estimated that access to piped water reduces mortality and increases life expectancy. In contrast, Sastry and Burgard (2005) did not observe an effect of water supply expansion on diarrhea cases in northeast Brazil. This evidence led Gamber-Rabindran, Khan and Timmins (2007) to use quantile regression analysis to identify if the effects of sanitation policies vary with the level of income of Brazilian municipalities. The authors found that access to water has little effect on municipalities with low or high income and a much greater effect on municipalities with income close to the mean, suggesting an optimal point at which the sanitation policy may affect infant mortality.

However, these studies focused on sanitation policies according to statements from individuals (census or PNAD) with regard to water access and sewage treatment; therefore, these studies may not capture the quality of water that reaches the homes of individuals or be able to determine if sewage is collected and treated, which is a point discussed by Kremmer et al. (2010). Furthermore, these studies focus on the impact of sanitation on infant mortality and/or life expectancy indicators. Although these health measures are important, they may not capture the public costs associated with health and related to hospitalizations.

This study seeks to establish sanitation indicators and traditional access methods by quantifying water quality and sewage treatment, and it also considers other health indicators, such as the

total morbidity and hospitalizations caused by diseases related to water scarcity or quality. We used data from the National Sanitation Information Service (Serviço Nacional de Informações de Saneamento - SNIS) to determine water and sewage access and quality indicators. The SNIS data are supplied by utility companies in each municipality. Our study is novel because we analyzed this information along with data from the Information Technology Department of the Brazilian Public Health System (Departamento de Informática do Sistema Único de Saúde – DATASUS) to identify mortality and hospitalizations per class of disease (hepatitis A, acute respiratory infections (ARI) and dysentery per 100,000 inhabitants) as the dependent variables. Finally, we also explored differences in the epidemiological transition stages that are managed by Brazilian municipalities and may lead to heterogeneous health results in these municipalities as suggested by Gamper-Rabrindan, Khan and Timmins (2007).

Regarding SNIS data, there are significant gaps in data, especially in the early years of our data panel. Because sanitation data are provided by utility companies, they may not collect these records regularly, especially if these indicators are poor or associated with previously poor indicators in the municipalities. Therefore, we propose a panel data methodology that corrects the selection bias that occurred because only certain municipalities reported sanitation information at certain points in time. To correct this selection bias, we assume that municipalities make decisions on whether to report their sanitation indicators at a certain point in time based on socioeconomic conditions and prior sanitation indicators. This municipality decision-making model is implemented with a fixed effect panel data model to estimate the relationship between sanitation indicators and health indicators. Thus, we managed to 'control' the probability of data reporting and validate our results.

Results in the international literature are similar to those found in Brazil. Barrera (1990), for example, found that maternal education and access to water can improve the health of children up to 15 years of age. Java and Vallaion (2003) in India, Galdo and Briceño (2005) in Ecuador, Checkley et al. (2004) in Peru, and Lee, Rosenweig and Pitt (1997) in Bangladesh and the Philippines found a positive effect of water access policies on the health of children. Esrey et al. (1991) reviewed several studies examining policies related to access to water and sewage and their effect on disease. In general, these policies have a positive impact on the morbidity of ascariasis, diarrhea, schistosomiasis and trachoma.

Watson (2006) estimated the positive effect of sanitation expansion in indigenous communities after 1950. The author found that a decrease in infant mortality of approximately 50% occurred three years after the policy was adopted. The study also identified other positive effects on health such as decreased prevalence of respiratory and gastrointestinal tract diseases. Finally, two studies estimated the effect of sanitation policies through field experiments, with Devoto et al. (Morocco; 2011) and Kremmer et al. (2011) finding positive results of sanitation policies on diarrhea in children up to five years of age. However, Greenstone and Hanna (2011) did not observe an effect of decreased air and water pollution on infant mortality in India.

Our results suggest a limited effect of sanitation policies on health. Lower water quality (total coliforms) is associated with increased infant mortality and morbidity (up to one year of age). Access to water is not associated with reduced infant mortality, although it is associated with decreased hospitalizations of children aged five and nine years of age and hospitalizations for dysentery and ARI. In turn, sewage sanitation is associated with reduced mortality and hospitalizations of children between one and four years of age and hospitalizations for dysentery. Finally, we provide evidence that this sewage sanitation effect is stronger in municipalities that have the worst mortality and morbidity indicators in this age group. Because strong effects of other sanitation policies were not observed in municipalities with the worst indicators, we cannot provide robust evidence on the epidemiological transition of Brazil. One of the possible explanations for the weak effect of sanitation policies on health indicators is that in the 2000s, water service was already close to universal, and limited improvements have been made in sewage and water, which is indicated in the graphs in section 2.

The present article is divided into six sections. Section 2 presents data on sanitation and health in Brazil; Section 3 describes the methodology developed in this study and relevance to the problem in question; Section 4 describes the main results; Section 5 presents evidence on Brazilian municipalities that are in different stages of epidemiological transition; and Section 6 provides a discussion of possible explanations for the modest effect of sanitation policies on health indicators. In the last section, the main conclusions are presented.

2. Sanitation and Health in Brazil

2.1- Sanitation

The first policy adopted by the Brazilian government to improve basic sanitation throughout the country was created in 1960 after the establishment of the National Housing Bank (Banco Nacional de Habitação – BNH), which allocates funds from the Brazilian Severance Pay Fund (Fundo de Garantia por Tempo de Serviço - FGTS), a type of compulsory savings fund for formal workers, to finance the sector by means of the Sanitation Financial System. The 1970s were important because the first sanitation program, the National Sanitation Plan (Plano Nacional de Saneamento - Planasa), was implemented in Brazil. This program granted rights to state sanitation companies to exploit water and sewage services financed by the BNH. In the 1990s, several federal programs aiming to increase the quality and reduce the inequality of access to sanitation services were adopted. These programs include the Modernization of the Sanitation Sector Program (*Programa de Modernização do Setor de Saneamento* - PMSS) of 1995, which provided technical support for the adoption of policies in the sector. In 1996, Act 8987 (Concessions Act) was passed, and it allows the private sector to provide sanitation services.

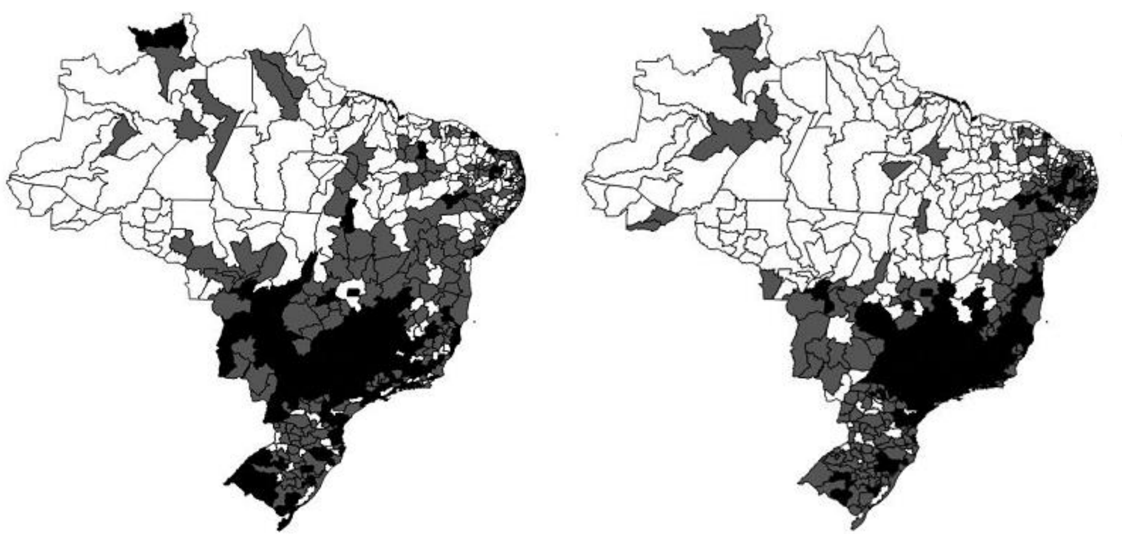
However, major legal changes were observed in the 2000s. Act 11107 of 2005 reinforces general hiring rules for the federal government, states, federal district and municipalities related to public consortia for performing objectives of common interest. In 2007, Act 11445, which is referred to as the sanitation act and sets forth national guidelines for basic sanitation, was passed. This act also determined that the use of water resources in the provision of public sanitation services,

including for the disposal or dilution of sewage and other liquid waste, is subject to use rights. Another important change in the sector occurred as a result of Act 9984, which provides for the creation of the National Water Agency (*Agência Nacional de Águas* - ANA), a federal entity that implements the National Policy of Water Resources and coordinates the National Water Resources Management System. Finally, Act 9984 sets forth that all municipalities must prepare local sanitation plans by 2013 under penalty of a reduction of federal funds. In addition, Ordinance 518 of 2004 addresses the compliance, control and monitoring of water quality for human consumption as well as the degree of potability. Finally, Brazil was a signatory to the *Millennium Development Goals of the United Nations*, which requires that Brazil reduce the rate of infant mortality by two thirds and increase the access to safe drinking water by one half by 2015.

The main consequence of these legal efforts is observed in data from demographic censuses from 1970 to 2000, in which piped water service coverage increased from 32.8% to 76.6% of households and the sewage collection network coverage increased from 13.1% to 46.5% of households.

Despite such improvements in services, access is still unequal. Water and sanitation access data in 2000 for the micro-regions of Brazil are presented in Figures 1A and 1B, which indicates a concentration of low indicators in the north and northeast regions despite improvements of the mean indicator. These figures are divided into three groups: higher access quantiles are darker, intermediary access quantiles are grey, and the worst access quantiles are lighter.

Figures 1A and 1B – Access to a general network of piped water (left) and sewage (right) among Brazilian micro-regions in 2000; separated into three quantile groups.



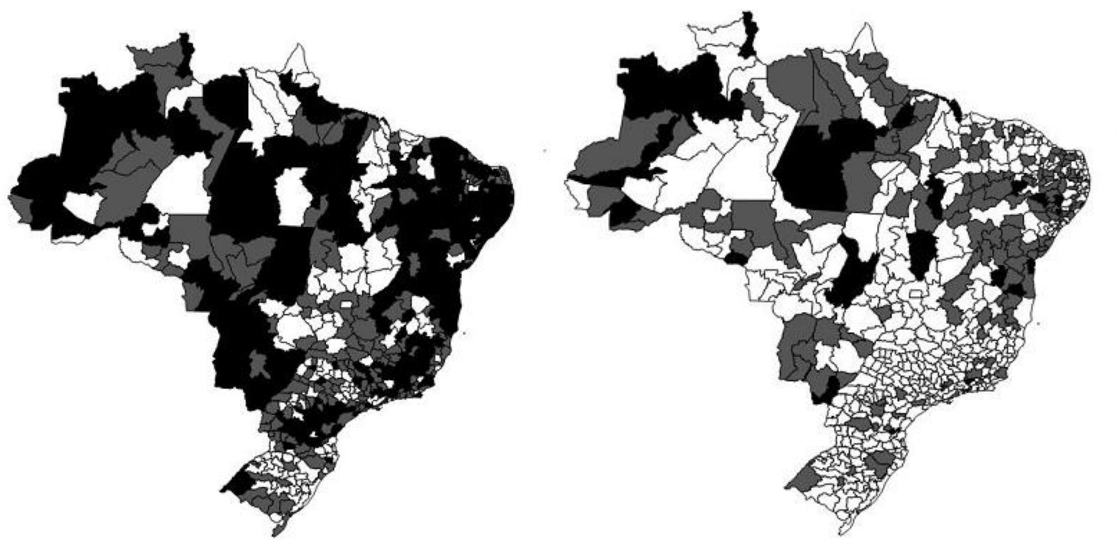
Source: 2000 Census. Software: ipeageo.

We observed that a regional dispersion pattern remained. The micro-regions of central-south Brazil exhibited higher sanitation indices than those in north-northeast Brazil. In all regions of the country, water access coverage is higher than sewage network coverage.

2.2 - Health

In the 1970 census, 123.2 deaths occurred in children below one year of age per 1000 live births, and this rate dropped to 83.2, 44.7 and 30.6 deaths per live births in the 1980, 1991 and 2000 censuses, respectively. Figures 2A and 2B show the distribution of infant mortality rates calculated from the number of infant deaths (up to one year of age) per 1000 live births for the Brazilian micro-regions in 2000 and 2010, respectively. In 2000, a limited number of micro-regions had infant mortality rates lower than 16 deaths per 1000 live births (lighter areas); however, by 2010, micro-regions with mortality rates lower than 16 deaths per 1000 live births had spread within the center of the country, whereas micro-regions with mortality rates higher than 22 deaths per 1000 live births (darker areas) had decreased.

Figures 2A and 2B - Mortality rate in children aged up to one year per 1000 live births among Brazilian micro-regions in 2000 (left) and 2010 (right) separated per quantile group.



Source: DATASUS. Prepared by the authors.

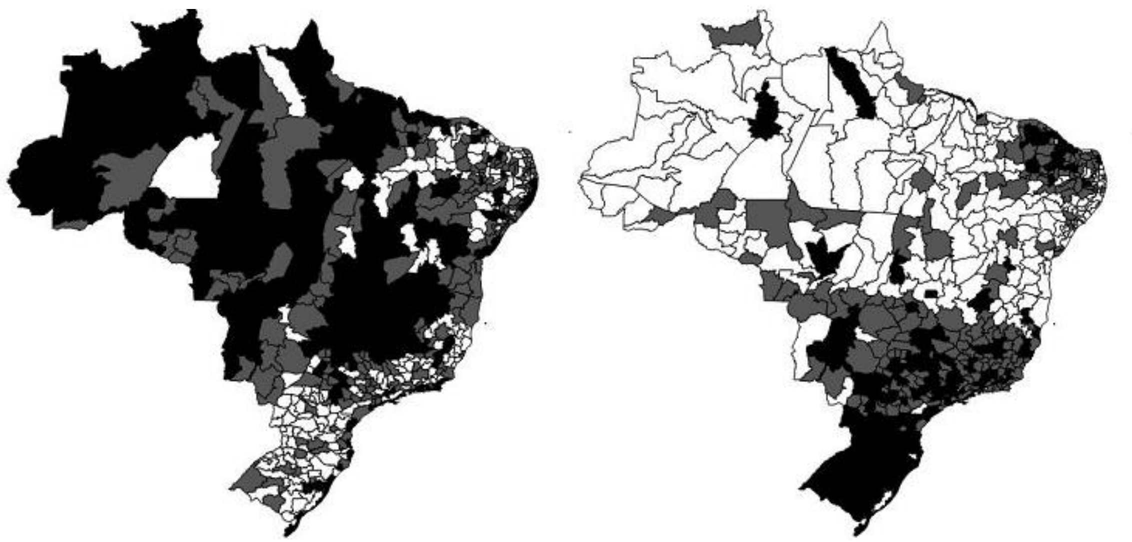
A decrease in mortality rates up to 16 per 1000 live births is concentrated in central-south Brazil. In the central-north and northeast Brazil mesoregions, although infant mortality rates decreased compared with the rate in 2000, the infant mortality rates are generally over 20 per 1000 live births.

This regional discrepancy appears to indicate heterogeneity among Brazilian cities in relation to the country's epidemiological transition. Sanders, Fuhrer, Johnson and Riddle (2008) stated that the epidemiological transition (Omran's Theory), a phenomenon in which countries transition from acquiring infectious diseases to degenerative diseases, can differ depending on the level of development of the countries. Their study found that with the establishment of sanitation and hygiene practices, vaccines and antibiotics, countries with improved economic conditions can

substantially reduce these infectious diseases. A possible consequence of this type of policy would be an increase in the percentage of degenerative diseases in these statistics.

The economic heterogeneity and size of Brazil provide an excellent opportunity to investigate, at least partially, Omran's Theory of Epidemiologic Transition, particularly because the health sector is federally regulated and the same incentives are provided to all municipalities. Thus, all federal units are governed under the same rules, and the only differences among municipalities are their development and health indicators. However, a preliminary investigation of these diseases is necessary. Figure 3 presents the spatial pattern of mortality caused by infectious diseases (regions still in epidemiological transition) compared with degenerative diseases (tumors).

Figures 3A and 3B – Mortality from infectious diseases (left) and tumors (right) presented as a ratio of the total mortality among Brazilian micro-regions in 2000.



Source: DATASUS. Software: ipeageo.

These maps show that less developed municipalities that have lower indicators of access to water and sanitation, such as those in the north region and part of the northeast region, have the highest rates of mortality from infectious diseases (darker areas in Figure 3A). Deaths from degenerative diseases (tumors) are concentrated in central-south Brazil, which is the most developed region (darker areas in Figure 3B). These maps reinforce, at least preliminarily, the hypothesis that Brazil is heterogeneous in terms of development and has regions at different stages of epidemiological transition. In the next section, we describe the data and empirical strategies used to estimate the relationship between sanitation and health.

2.3 Database and Descriptive Analysis

This study presents a novel use of two databases related to sanitation and health. The SNIS is a database maintained by the federal government's Ministry of the Cities, and it contains information on water and sewage providers in each municipality. In this study, we used SNIS data from 2003 to 2010. The rates of access to water and sewage were represented by the percentage of the total population in a given municipality that has access to water, percentage of the total population of a given municipality that has access to sewage collection and percentage of the population receiving sewage collection that has access to sewage treatment[1]. In addition, the method established here calculates service inefficiency as the percentage of losses that occur during water distribution. Finally, we used the indices of non-standard turbidity analyses, non-standard total coliforms analyses and non-standard residual chlorine analyses as water quality measures.

The number of municipalities that report information to SNIS varies markedly from indicator to indicator. In 2010, a total of 4,935 municipalities among 5,564 reported information on water service, whereas only 1,632 municipalities reported information on sewage collection. The sewage system in Brazil is less developed than the water access system. In certain Brazilian municipalities, the utility company only provides services related to water and is not involved in sewage collection or treatment. In addition, the number of municipalities that report information varies over time. For example, approximately 1,170 municipalities reported information on sewage collection in 2006, whereas only 4,300 answered questions related to water access.

Health indicators are extracted from the database of the Public Health System (Sistema Único de Saúde - SUS), which is known as DATASUS. Using this database, we obtained the rates of hospitalizations and deaths that will be used as health indicators in this study. The indicators were assessed per age group and per diseases. The infant mortality indicator is frequently used in the literature to determine the impact of basic sanitation. When an individual has access to piped water, which provides improved hygiene and cleanliness, they do not have to obtain access to sanitation that may be of doubtful quality. The indicators used in this study are deaths per 1,000 live births per age group (under 1 month, 1 to 12 months, 1 to 4 years and 5 to 9 years) and hospitalizations per age group (1 to 12 months, 1 to 4 years and 5 to 9 years).

In turn, the lack of sewage collection and treatment increases the frequency of contact with sewage, which increases the incidence of disease. Galdo and Briceño (2005) list four classes of disease that are directly or indirectly acquired from water, including diseases caused by poor water quality that is contaminated by sewage; diseases related to insufficient water volume for personal hygiene; diseases caused by waterborne organisms, such as schistosomiasis and worms; and diseases transmitted by insects that breed in water and polluted environments. These diseases may cause hospitalizations and can result in death.

[1] In most cases, the sanitation company considers 1 as "collection services available" and 0 as "no collection services available," which generates concentration of this variable at 0% or 100%.

Children are more susceptible to the first two classes of diseases as a result of their greater likelihood of coming into contact with sewage compared with adults and because they suffer more as a result of insufficient water volume. These effects can be exacerbated in children, especially children aged up to one month and between five and nine years because they have a greater likelihood of complications compared with adults.

Thus, we used the number of hospitalizations for certain diseases per 100,000 inhabitants as a health indicator. The diseases were those related to sanitation quality and infectious diseases that mainly affect children, including diarrhea, dysentery, hepatitis, and ARI[2]. These diseases are related to contaminated water without treatment, and they can be established by our quality indicators. In addition, these diseases may also be related to a lack of water (access) for personal hygiene.

We also used other variables as controls in our model. The population of each Brazilian municipality was estimated in July 1st of each year by the IBGE for the period 2003 to 2006 and years 2008 and 2009. In 2007, the IBGE performed a population count, and in 2010, they performed a demographic census. The gross domestic product (GDP) of each municipality was also calculated by the IBGE[3]. The educational level of the municipality was determined by the ratio of children between zero and six years of age who were enrolled in daycares or preschools, which was constructed with data from school censuses from 2003 to 2011. In addition, we considered the rate of vaccination coverage of each municipality and percentage of the population served by the Family Health Program (*Programa Saúde da Família*). Both datasets were extracted from DATASUS.

Table 1 summarizes the descriptive statistics of all variables used in the study, which are grouped from 2003 to 2010. The mean number of hospitalizations for ARI is high (11.36 per 100,000 inhabitants) in relation to hepatitis (0.07) or dysentery (2.6). Approximately 65% of the municipalities had water service from 2003 to 2010, and approximately 36% had sewage treatment. The vaccination coverage is 81% on average.

Panels 1 and 2 present changes in water and sewage indicators for each Brazilian region. These graphs indicate that water service is much lower in the north and northeast regions of Brazil compared with other Brazilian regions. Sewage collection and treatment are much higher in southeast Brazil compared with other regions. These graphs also indicate limited variation in water and sanitation access indicators over time. The non-standard chlorine index is much higher in the north and northeast regions compared with the rest of Brazil.

[2] In a preliminary version of the study, we considered the following health indicators: hospitalizations for diseases such as tuberculosis and tetanus. The results are available upon request to the authors.

[3] We used the logarithm of the population in our models. According to the IBGE (2008), the GDP is decreased by an implicit deflator of the national GDP and is calculated according to the distribution of added value of the main local economic activities.

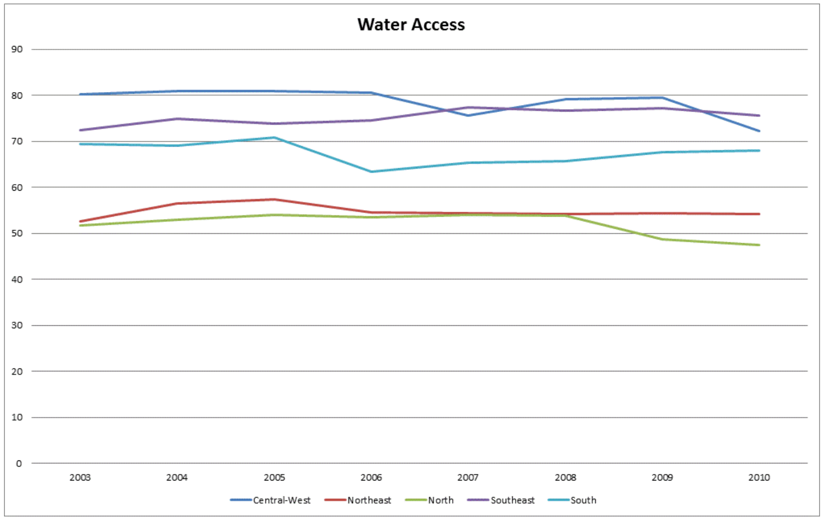
Panel 3 presents changes in the death indicators and shows that death rates of infants up to one-month of age are decreasing throughout Brazil, and the highest number of deaths is observed in the north and northeast regions. However, this trend does not occur in relation to deaths of children from 1 to 12 months of age, which has recently increased in the north region. Panel 3 presents changes in hospitalizations per age group. The number of hospitalizations of children aged five to nine has increased and is higher in the south and central-west regions of Brazil. Panel 4 presents changes in the hospitalizations per type of disease. Hospitalizations for diarrhea, dysentery and hepatitis are higher in the north and northeast regions, whereas hospitalizations for ARI are higher in southern Brazil. Most of the ARI hospitalizations in the south region are associated with the colder climate of the area. All of the panels emphasize the heterogeneous evolution of health and sanitation indicators in the Brazilian regions.

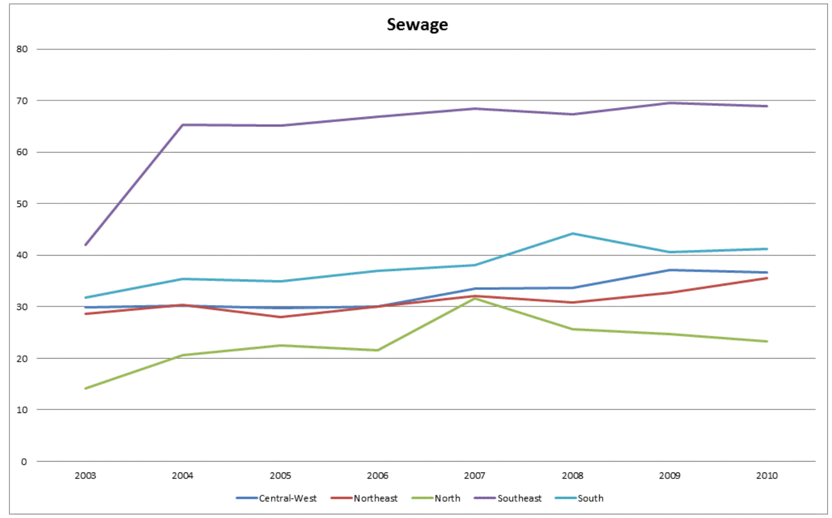
Table 1: Descriptive Statistics

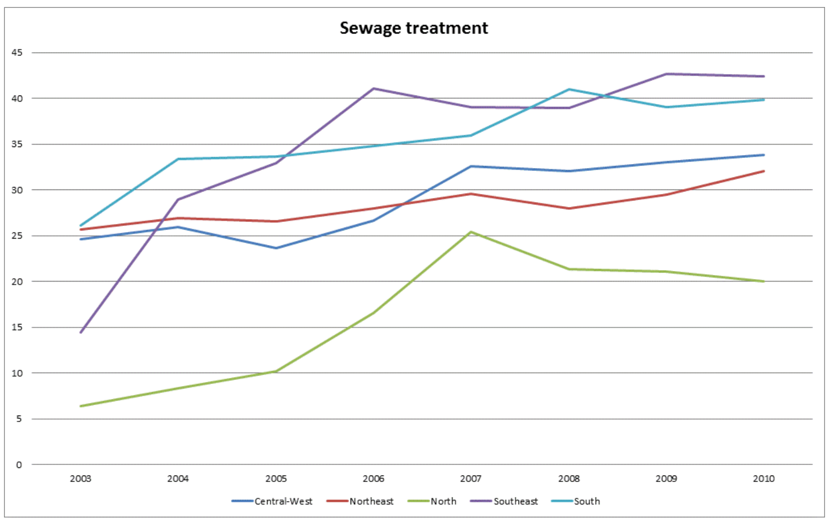
	Observations	Average	Std. Dev.	Minimum	Maximum
Deaths per 1000 live births (Mortality)					
less than 1-month old	31120	16.39	14.10	0	400
from 1- to 12-months old	31120	5.34	7.86	0	242.42
from 1- to 4-years old	31120	2.49	6.19	0	343
from 5- to 9-years old	31120	1.49	6.88	0	1000
Hospitalizations per 1000 live births (Morbidity)					
less than 1-year old	31120	17.71	15.72	0	1000
from 1- to 4-years old	31120	26.57	25.39	0	1416.67
from 5- to 9-years old	31120	17.44	17.11	0	482.14
Hospitalizations per 100000 inhabitants					
Diarrhea	31115	1.88	3.61	0	64.97
Hepatitis	31115	0.07	0.14	0	3,82
Dysentery	31118	2.60	4.36	0	80.27
ARI	31115	11.36	8.73	0	162.76
Sanitation variables					
Water access	29368	65.37	24.73	0	100
Sewage	8518	51.86	31.79	0	906.3
Sewage treatment	8286	35.67	32.34	0	589.10
Losses index	28338	33.41	38.54	-5375	100
Non-standard chlorine index	25901	4.18	12.28	0	100
Non-standard turbidity index	25856	5.89	14.31	0	100
Non-standard total coliforms index	25843	2.48	8.58	0	100
Control Variables					
GDP per capita	31117	4262.35	9681.16	0.18	296786.30
Population (log)	31115	9.58	1.18	6.69	16.24
Childhood education	42933	1.01	0.42	0	6.36
Immunization coverage	31118	81.38	11.20	30.11	287.86
Saude da Família´s program attendance	30850	0.86	0.39	0	7.46

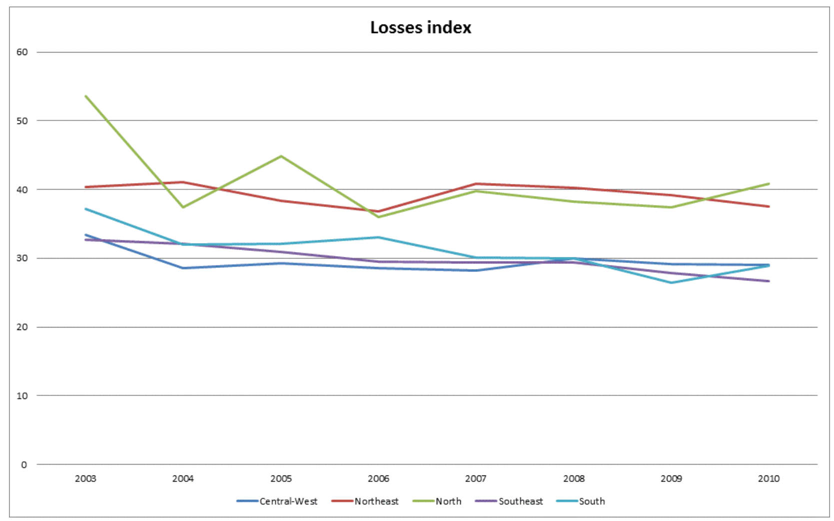
Sources: SNIS, DATASUS, Education Census and Population Census

Panel 1: Evolution of Water and Sewage Indicators per Brazilian Region

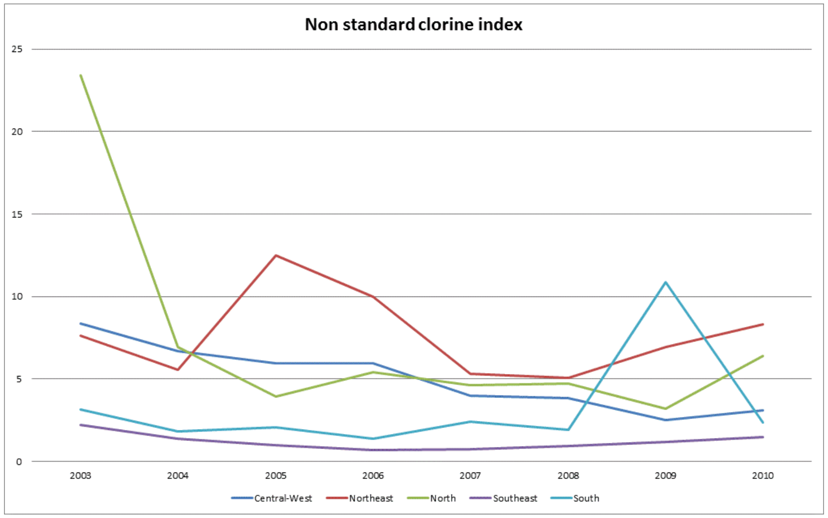


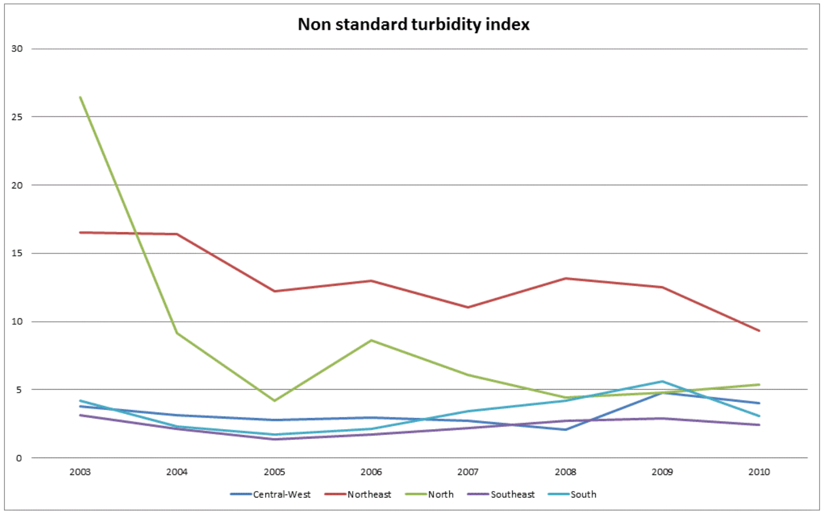


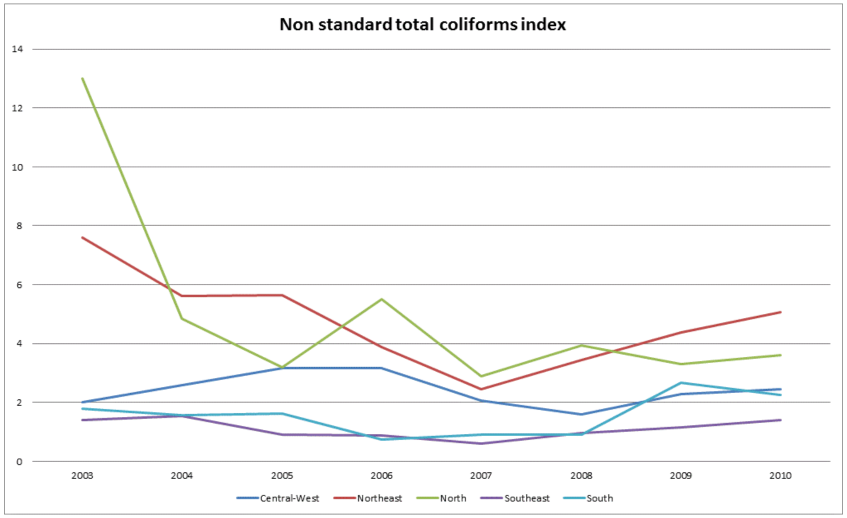




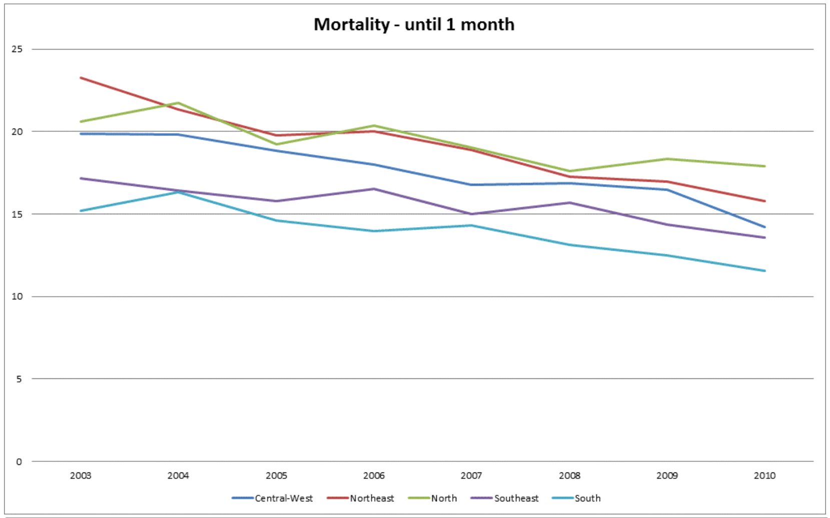
Panel 2: Evolution of Water Quality Indicators per Brazilian Region

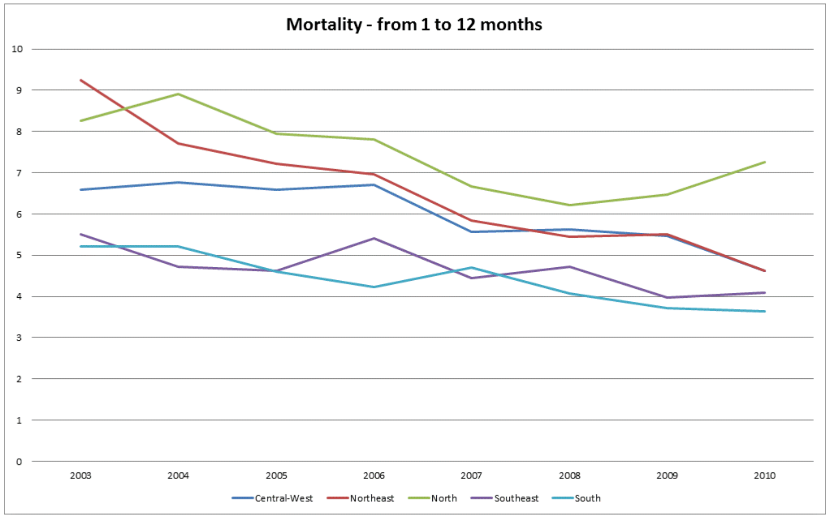


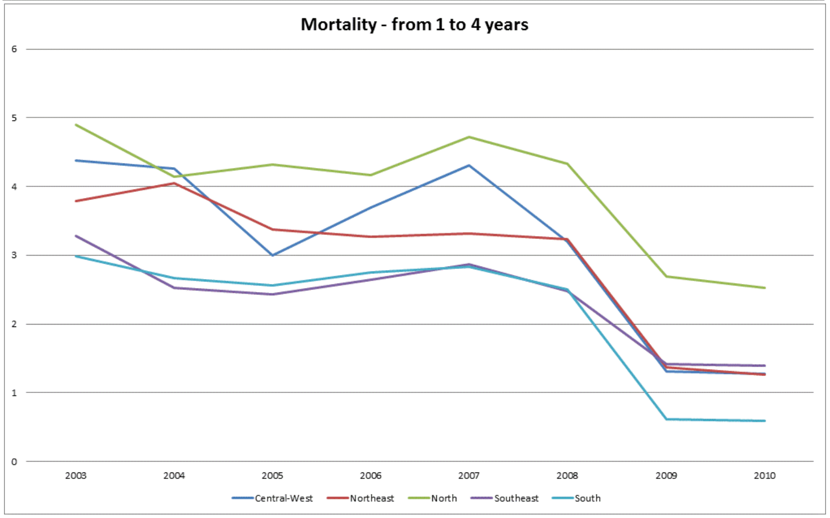


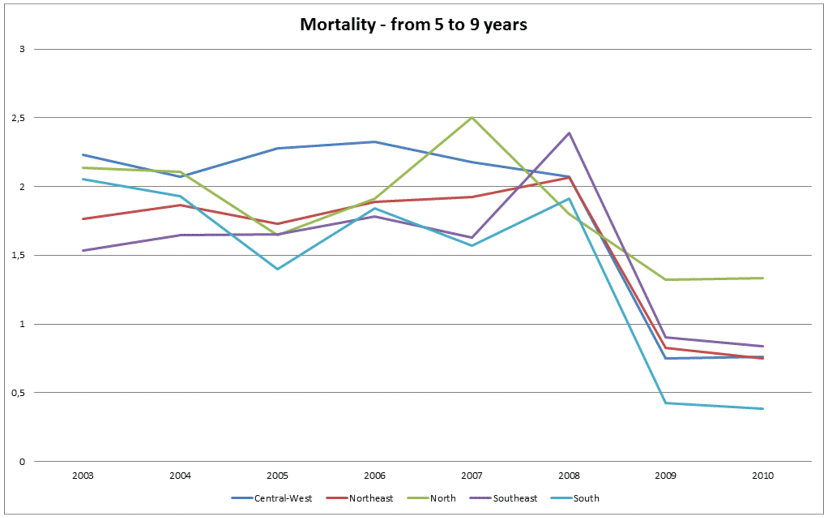


Panel 3: Evolution of Death Indicators per Brazilian Region

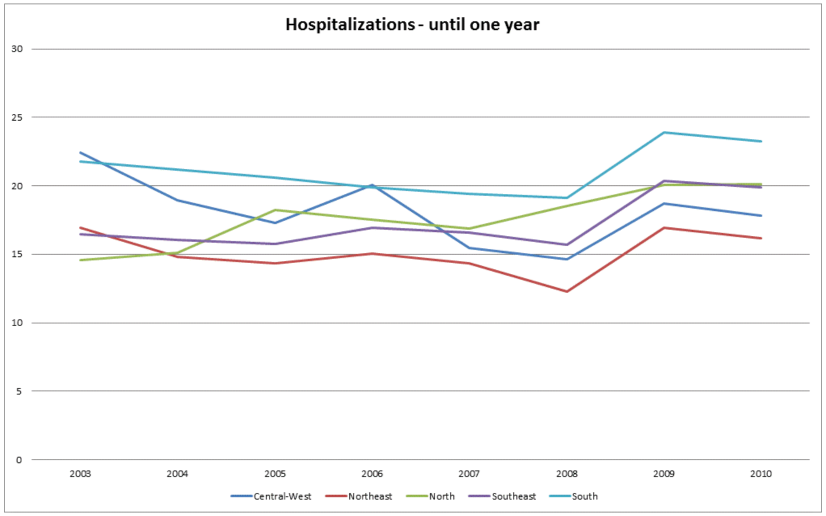


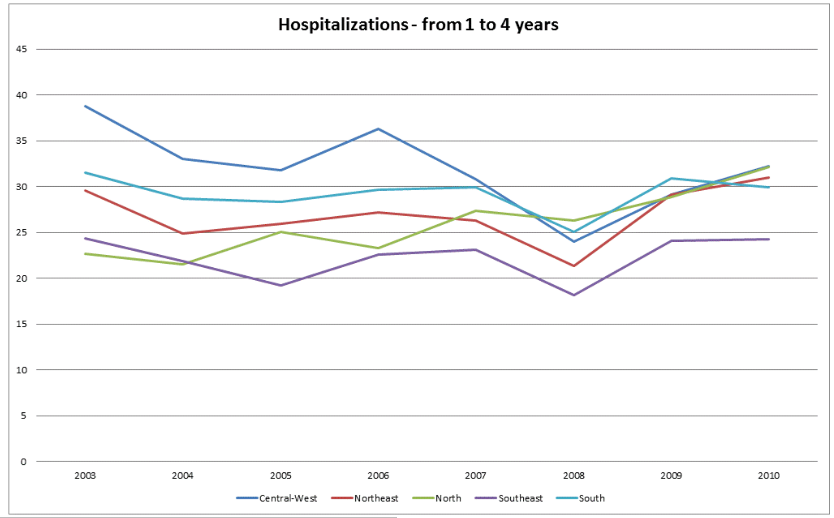


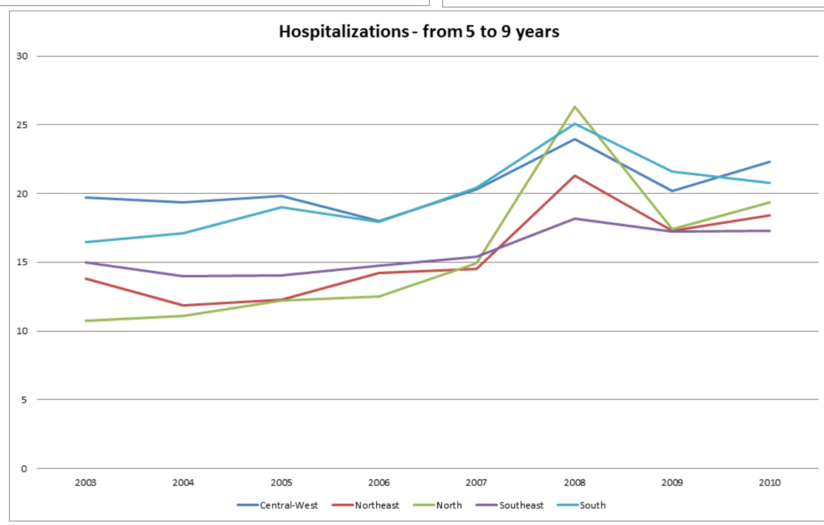




Panel 4A: Evolution of Hospitalization Indicators per Brazilian Region







Panel 4B: Evolution of Hospitalizations per Disease per Brazilian Region

3. Empirical Strategy

To estimate the effect of sanitation indicators on health variables, we used a panel data model with fixed effects. In this model, we have included past health indicators. As emphasized by several authors (Watson, 2006 and Smith, 2007), changes in sanitation infrastructure affect health variables during the period of change as well as future indicators. In this article, we used the following fixed-effect panel model:

(1)
$$IndHealth_{it} = \beta_0 + \beta_1 IndWater_{it} + \beta_2 IndWater_{it-1} + \beta_3 IndWater_{it-2} + \alpha Controls_{it} + a_i + t\eta_{CO} + t\eta_N + t\eta_{NO} + t\eta_S + t\eta_{SU} + u_{it}$$

where *IndHealth*$_{it}$ represents health indicators for municipality i in period t, *IndWater* represents all variables related to water access, water quality, sewage treatment and collection, and *Controls* represents other model explanatory variables. In addition, a fixed effect was included in the model for each municipality (a_i), and a non-linear trend was included per Brazilian region. This trend is formed by the interaction between a binary variable that is equal to 1 if municipality i is in region j (η_j) and a linear trend (t). These trends can capture different trajectories of health variables among Brazilian regions. As previously mentioned, the vector of controls includes the logarithm of the population of each municipality, GDP per capita of each municipality, percentage of the population zero to six years of age that is enrolled in early childhood education, degree of vaccination coverage in the municipality and percentage of the population served by the family health program. In addition, we included sanitation variables (*IndWater)* for the previous period (t-1) and two previous periods (t-2).

Because the number of municipalities that report information to the SNIS increases over time, if we only estimate the panel for municipalities that reported information throughout the entire period from 2003 to 2008, a large number of municipalities will be left out of the estimation. If these municipalities had the worst sanitation infrastructure at the beginning of the period, the results will be biased. In this case, the results would only represent the effect of sanitation on health indicators for municipalities with a good sanitation infrastructure, and the effects of sanitation for Brazil as a whole would be underestimated. To verify if panel attrition is related to prior variables in the municipalities and determine if such attrition would generate a bias in our results, two attrition tests used in the literature were implemented here. The first is a modified version of the test used by Becketti, Gould, Lillard and Welch (1988). In our model, the sample grows over the period from 2003 to 2010; thus, to verify if municipality records are related to their prior water and sewage indicators, we used a test that relates the health indicator in 2010 with sanitation indicators in the same year and a variable that is equal to the health indicator in 2010 if the municipality appears in any of the previous years and equal to 0 otherwise. In this test, we estimated the following model:

(2)
$$IndHealth_{i2010} = \beta_0 + \beta_1 IndWater_{i2010} + \beta_2 L_i \cdot IndWater_{i2010} + u_{i2010}$$

where L_i is equal to 1 if the municipality appeared in the sample in any previous period (2003, 2004, 2005, 2006, 2007, 2008 and 2009). In this case, the significance of coefficient β_2 is tested. If attrition is completely random, this coefficient should be non-significant because the second variable does not add any new information to the regression. The second test was proposed by Nijmann and Verbeek (1992) in which the fixed effects model is estimated and includes sanitation variables from one and two previous periods and binary variables that indicate if municipality i appeared in the previous periods.

(3) $$IndHealth_{it} = \beta_0 + \beta_1 IndWater_{it} + \beta_2 IndWater_{it-1} + \beta_3 IndWater_{it-2} \\ + \alpha Controls_{it} + \eta_1 s_{it-1} + \eta_2 s_{it-2} + a_i + \delta_t + u_{it}$$

where s_{it-1} is equal to 1 if the municipality appeared in the sample in period t-1 and equal to 0 otherwise. Similarly, s_{it-2} is equal to 1 if the municipality appeared in the sample in period t-2 and equal to 0 otherwise. In this test, we examined the statistical significance of the coefficients associated with s_{it-1} and s_{it-2}.

Tables 2 and 3 present the results for the tests of Becketti, Gould, Lillard and Welch (1988) and Nijmann and Verbeek (1992), respectively. The results in Table 3 indicate that attrition is not random and show that it is related to the population size and sewage collection in the previous period. The results of the second test confirm this result. In Table 4, at least one coefficient associated with s_{it-1} and/or s_{it-2} is significant in nearly all models.

To correct for bias in the results generated by attrition, we used a model for municipality decision-making related to reporting information on a variable to the SNIS over time. The likelihood of the municipality reporting information to the SNIS in period t will be a function of the sanitation indicators in past periods and lagged explanatory variables. The function indicating whether the municipality is included in the SNIS database is as follows:

(4) $$s_{it} = \begin{cases} 1\,if & \varpi_{it} > -\varphi_0 - \varphi_{it} w_{it} \\ 0\,if & \varpi_{it} \leq -\varphi_0 - \varphi_{it} w_{it} \end{cases}$$

where $w_{it} = [IndWater_{it-1}, IndWater_{it-2}, controls_{it-1}, controls_{it-2}], t = 2005,...,2010.$

In addition, we assume that $\varpi_{it} | \Delta x_{it}, w_{it}$ is a non-observed variable that has a normal distribution with a mean of zero and variance of one.

In this corrected model, model (1) is used in the first difference form:

(5) $$\Delta IndHealth_{it} = \beta \Delta x_{it} + \Delta t \eta_{CO} + \Delta t \eta_N + \Delta t \eta_{NO} + \Delta t \eta_S + \Delta t \eta_{SU} + \Delta u_{it} \\ \Delta x_{it} = [\Delta IndWater_{it}, \Delta IndWater_{it-1}, \Delta IndWater_{it-2}, \Delta Controls_{it}]$$

Table 2a: Attrition Test Result - Becketti, Gould, Lillard and Welch (1988)

	Mortality			
	1 month	1 year	1-4 years	5-9 years
Water access	-0.0386**	-0.0256***	-0.0475***	-0.0288***
	(0.0160)	(0.00861)	(0.0178)	(0.00990)
Sewage treatment	0.0125	0.00662	0.0179	0.0137*
	(0.0114)	(0.00521)	(0.0128)	(0.00744)
Losses index	0.0145	0.00323	-0.0448	-0.0264*
	(0.0194)	(0.00864)	(0.0279)	(0.0148)
Non standard chlorine index	-0.00639	0.0238	0.0163	0.0230
	(0.0557)	(0.0297)	(0.0443)	(0.0371)
Non standard turbidity index	0.0158	-0.0230**	-0.0219	-0.00465
	(0.0271)	(0.0116)	(0.0218)	(0.0142)
Non standard total coliforms index	-0.0744	-0.00714	-0.0182	-0.0143
	(0.0506)	(0.0253)	(0.0317)	(0.0222)
GDP per Capita	-2.62e-05	1.18e-05	3.66e-05*	2.33e-05**
	(1.69e-05)	(1.32e-05)	(1.90e-05)	(1.09e-05)
Saude da Família´s program attendance	1.085*	-0.000151	-0.754***	-0.460***
	(0.638)	(0.215)	(0.275)	(0.167)
Immunization coverage	0.0789***	0.0347***	-0.279***	-0.161***
	(0.0290)	(0.0122)	(0.0808)	(0.0416)
Childhood education	1.526	0.327	-1.472	-1.024**
	(1.176)	(0.540)	(0.897)	(0.499)
L. Sewage	-0.0115	-0.00617	0.00159	-0.000433
	(0.0115)	(0.00506)	(0.00977)	(0.00607)
L. log population	0.754***	0.268**	2.986***	1.754***
	(0.216)	(0.104)	(0.734)	(0.378)
Observations	1,185	1,185	1,185	1,185
R-squared	0.617	0.367	0.218	0.252

*** p<0.01, ** p<0.05, * p<0.1

Table 2b: Attrition Test Result - Becketti, Gould, Lillard and Welch (1988)

	Morbidity						
	1 year	**1-4 years**	**5-9 years**	**dysentery**	**hepatitis**	**IRA**	**diarrhea**
Water access	0.0689***	0.142***	0.0848***	0.00206	0.000221*	0.0700***	0.000478
	(0.0176)	(0.0325)	(0.0174)	(0.00488)	(0.000131)	(0.0113)	(0.00613)
Sewage treatment	0.0313**	0.0615**	0.0315**	0.00801***	-6.98e-05	0.0317***	0.00652***
	(0.0129)	(0.0250)	(0.0145)	(0.00278)	(0.000121)	(0.00807)	(0.00245)
Losses index	-0.0146	-0.0903**	-0.0589***	-0.00779	0.000137	-0.0595***	-0.00928
	(0.0197)	(0.0372)	(0.0210)	(0.00591)	(0.000184)	(0.0136)	(0.00564)
Non standard chlorine index	0.00690	0.0289	0.0202	-0.00289	-0.000140	-0.0302	0.0459
	(0.0413)	(0.113)	(0.0649)	(0.0198)	(0.000261)	(0.0386)	(0.0281)
Non standard turbidity index	-0.0808***	-0.128**	-0.0701**	-0.00709	-0.000278*	-0.0639***	-0.0121
	(0.0246)	(0.0526)	(0.0334)	(0.00908)	(0.000165)	(0.0196)	(0.00786)
Non standard total coliforms	0.0183	0.0481	0.00719	0.00271	0.000394	0.0168	-0.0177
index	(0.0464)	(0.127)	(0.0755)	(0.0179)	(0.000479)	(0.0598)	(0.0165)
GDP per Capita	-4.67e-05***	-0.000161***	-9.02e-05***	-1.53e-05***	-2.30e-07***	-4.79e-05***	-1.79e-05***
	(1.37e-05)	(3.13e-05)	(1.92e-05)	(4.08e-06)	(8.90e-08)	(8.64e-06)	(4.88e-06)
Saude da Família´s program	0.489	1.565	2.227**	0.195	0.00482	0.933**	0.215*
attendance	(0.554)	(0.990)	(0.891)	(0.140)	(0.00623)	(0.403)	(0.130)
Immunization coverage	0.213***	0.524***	0.295***	0.0405***	0.000255	0.165***	0.0267***
	(0.0327)	(0.0515)	(0.0294)	(0.00701)	(0.000200)	(0.0177)	(0.00714)
Childhood education	-0.366	-0.704	-1.831*	-0.349	0.00210	-2.288***	0.0450
	(0.930)	(1.508)	(0.934)	(0.228)	(0.00651)	(0.572)	(0.206)
L. Sewage	-0.0184	-0.0902***	-0.00828	-0.0171***	-1.26e-05	-0.0287***	-0.00790**
	(0.0137)	(0.0274)	(0.0157)	(0.00342)	(0.000114)	(0.00865)	(0.00315)
L. log population	0.0734	-1.510***	-0.689***	-0.0319	0.000508	-0.250**	-0.0118
	(0.228)	(0.374)	(0.217)	(0.0466)	(0.00163)	(0.125)	(0.0561)
Observations	1,185	1,185	1,185	1,185	1,185	1,185	1,185
R-squared	0.792	0.688	0.748	0.251	0.248	0.686	0.210

*** p<0.01, ** p<0.05, * p<0.1

Table 3a: Attrition Test Result - Nijmann and Verbeek (1992)

	Mortality			
	1 month	1 year	1-4 years	5-9 years
Water access	0.0301	0.0301	-0.0155	-0.0154*
	(0.0220)	(0.0220)	(0.0134)	(0.00889)
Sewage	-0.0249*	-0.0249*	-0.0148	-0.00906
	(0.0149)	(0.0149)	(0.00907)	(0.00603)
Sewage treatment	0.00886	0.00886	-0.000735	0.00587
	(0.0136)	(0.0136)	(0.00828)	(0.00550)
Losses index	-0.0123	-0.0123	0.00271	-0.00132
	(0.0121)	(0.0121)	(0.00738)	(0.00490)
Non standard chlorine index	-0.0236	-0.0236	-0.0140	-0.00594
	(0.0226)	(0.0226)	(0.0138)	(0.00917)
Non standard turbidity index	-0.0245	-0.0245	-0.00912	-0.00491
	(0.0214)	(0.0214)	(0.0130)	(0.00866)
Non standard total coliforms	-0.00873	-0.00873	0.00347	-0.00463
index	(0.0408)	(0.0408)	(0.0249)	(0.0165)
GDP per Capita	4.99e-05***	-4.99e-05***	4.40e-05***	1.57e-05***
	(1.30e-05)	(1.30e-05)	(7.92e-06)	(5.26e-06)
Population (log)	3.235	3.235	0.206	-0.0798
	(2.350)	(2.350)	(1.433)	(0.952)
Saude da Família´s program	-1.857***	-1.857***	0.565	0.620**
attendance	(0.719)	(0.719)	(0.438)	(0.291)
Immunization coverage	0.643	0.643	-0.549	-0.295
	(0.603)	(0.603)	(0.368)	(0.244)
Childhood education	-0.0255	-0.0255	0.00601	-0.000610
	(0.0186)	(0.0186)	(0.0114)	(0.00754)
s_{t1}	-0.917	-0.917	0.233	0.407
	(0.774)	(0.774)	(0.472)	(0.314)
s_{t2}	-2.273***	-2.273***	0.189	0.259
	(0.439)	(0.439)	(0.267)	(0.178)
Constant	-12.75	-12.75	1.211	2.974
	(25.00)	(25.00)	(15.24)	(10.12)
Observations	7,268	7,268	7,268	7,268
R-squared	0.016	0.016	0.008	0.006

*** p<0.01, ** p<0.05, * p<0.1

Table 3b: Attrition Test Result - Nijmann and Verbeek (1992)

				Morbidity			
	1 year	1-4 years	5-9 years	diarrhea	dysentery	hepatitis	IRA
Water access	0.0260	-0.0834**	-0.0183	-0.00195	-0.0166***	-0.000513**	-0.0339***
	(0.0252)	(0.0351)	(0.0274)	(0.00319)	(0.00302)	(0.000210)	(0.00698)
Sewage	-0.0223	-0.0290	-0.0229	0.00110	-0.000806	4.73e-05	-0.00558
	(0.0171)	(0.0238)	(0.0186)	(0.00216)	(0.00205)	(0.000142)	(0.00473)
Sewage treatment	0.0164	0.0149	0.0210	-0.00136	-0.00145	-0.000222*	-0.00268
	(0.0156)	(0.0217)	(0.0170)	(0.00197)	(0.00187)	(0.000130)	(0.00432)
Losses index	-0.00637	0.00371	-0.000329	0.000980	0.000989	1.93e-05	0.00566
	(0.0139)	(0.0194)	(0.0151)	(0.00176)	(0.00167)	(0.000116)	(0.00384)
Non standard clorine index	0.0158	0.0381	-0.0125	-0.00166	-0.00267	-0.000318	-0.00840
	(0.0260)	(0.0362)	(0.0283)	(0.00329)	(0.00312)	(0.000216)	(0.00719)
Non standard turbidity index	0.00281	0.0110	0.00217	-0.00421	0.00418	0.000251	0.0110
	(0.0246)	(0.0342)	(0.0267)	(0.00311)	(0.00295)	(0.000204)	(0.00680)
Non standard total coliforms	0.0367	-0.00445	-0.0320	-0.00436	-0.00492	0.000187	0.0146
index	(0.0468)	(0.0652)	(0.0510)	(0.00592)	(0.00562)	(0.000389)	(0.0130)
GDP per Capita	0.000142***	0.000110***	4.36e-06	-2.61e-06	-4.04e-06**	-5.24e-07***	6.92e-06*
	(1.49e-05)	(2.08e-05)	(1.62e-05)	(1.89e-06)	(1.79e-06)	(1.24e-07)	(4.13e-06)
Population (log)	-2.225	-1.158	5.179*	-2.163***	-4.860***	-0.0598***	-17.59***
	(2.699)	(3.760)	(2.937)	(0.341)	(0.324)	(0.0224)	(0.747)
Saude da Família´s program	-0.617	-1.285	-1.012	-0.0191	-0.0793	0.0102	-1.004***
attendance	(0.825)	(1.149)	(0.898)	(0.104)	(0.0989)	(0.00686)	(0.228)
Immunization coverage	0.593	0.646	1.845**	0.165*	0.452***	-0.00339	1.181***
	(0.693)	(0.965)	(0.754)	(0.0876)	(0.0830)	(0.00576)	(0.192)
Childhood education	0.0258	0.0726**	0.00444	-0.00421	-0.00252	0.000379**	0.0173***
	(0.0214)	(0.0298)	(0.0233)	(0.00270)	(0.00256)	(0.000178)	(0.00591)
s_{t1}	-0.786	-1.082	0.340	-0.218*	-0.227**	-0.0113	-0.358
	(0.889)	(1.238)	(0.967)	(0.112)	(0.107)	(0.00739)	(0.246)
s_{t2}	-0.841*	-1.538**	1.481***	0.159**	-0.127**	-0.00192	-0.978***
	(0.504)	(0.701)	(0.548)	(0.0637)	(0.0604)	(0.00419)	(0.139)
Constant	39.51	41.96	-35.77	24.21***	53.55***	0.702***	195.8***
	(28.71)	(39.99)	(31.24)	(3.630)	(3.442)	(0.239)	(7.942)
Observations	7,268	7,268	7,268	7,268	7,268	7,268	7,268
R-squared	0.019	0.008	0.006	0.013	0.070	0.011	0.149

*** p<0.01, ** p<0.05, * p<0.1

If a municipality did not report the information in t-1, then its probability of reporting the information in t is not affected, and the conditional expectation of the error of this equation will depend on the error in the probability of the municipality reporting information in t and t-1, and it will not depend on the interaction between these two errors:

(6) $$E[\Delta u_{it} | \Delta x_{it}, w_{it}, s_{it} = 1, s_{it-1} = 1] = \rho_1 \varpi_{it} + \rho_2 \varpi_{it-1}$$

Using this equation and the model in its first difference form, we obtained the following expression for conditional expectations of variation among health indicators:

(7) $$E\left[\Delta IndHealth_{it} | \Delta x_{it}, w_{it}, s_{it} = 1, s_{it-1} = 1\right] = \beta \Delta x_{it} + \Delta \delta_t + \rho_1 E\left[\varpi_{it} | \varpi_{it} > -\varphi_0 - \varphi_{it} w_{it}\right] + \rho_2 E\left[\varpi_{it-1} | \varpi_{it-1} > -\varphi_0 - \varphi_{it} w_{it-1}\right]$$

Using the normal distribution properties, the following linear model is established:

(8) $$\Delta IndHealth_{it} = \beta\Delta x_{it} + \Delta t\eta_{CO} + \Delta t\eta_{N} + \Delta t\eta_{NO} + \Delta t\eta_{S} + \Delta t\eta_{SU} + \rho_1\lambda(\delta w_{it}) + \rho_2\lambda(\delta w_{it-1}) + \xi_{it}$$

$$\lambda(\delta w_{it}) = \frac{\phi(\delta w_{it})}{\Phi(\delta w_{it})}, \lambda(\delta w_{it-1}) = \frac{\phi(\delta w_{it-1})}{\Phi(\delta w_{it-1})}$$

where $\lambda(\delta w_{it})$ and $\lambda(\delta w_{it-1})$ represent the functions that control the bias caused by the municipalities not reporting information to the SNIS over time.

To estimate this final model, we used a two-step procedure. In the first step, we estimated a probit model that relates the indicator of municipality i reporting information in period t (s_{it}) as vector $w_{it.}$ In this first step, we estimated the correction terms $\lambda(\delta w_{it})$ and $\lambda(\delta w_{it-1})$. In the second step, we estimated a linear regression that relates variation of health indicators with variations of explanatory variables, including variation of the trends per region and correction terms. The standard errors are calculated by bootstrap. In the following section, we will present the results obtained for the model with endogeneity-uncorrected data as well as the model estimated by this two-step procedure.

4. Mean Effect of Sanitation on Health

This section is divided as follows: section 4.1 presents the results related to mortality, and section 4.2 presents a discussion of the results related to hospitalizations. The mortality results are listed in Tables 4a and 4b, and hospitalization results are presented in Tables 5a and 5b. In all tables, we present the results of the model that includes a lagged sanitation variable from the two previous periods and bias correction for attrition. These models usually have the highest explanatory power and can include variations of sanitation policies lagged by up to two periods, which is similar to the model of Watson (2008). We focused our analysis on variables with at least a 5% significance level. In appendix A1, we present the results of the first step of this procedure, which estimated the factors related to the probability of the municipality reporting information to the SNIS in period t. In appendix A2, we present the models estimated without correction.

4.1 - Sanitation and Mortality

Tables 4a and 4b present the relationships between mortality indicators and sanitation indicators. Column (1) presents the results for mortality of children up to 1-month, column (2) presents the results for children between 1 and 12 months, column (3) presents the results for children between 1 and 4 years, and column (4) presents the results for children between 5 and 9 years.

We found that the sanitation policies appear to have a limited effect on reducing the mortality of children between one month and one year of age, which corroborates the results of Ortiz and Oshiro (2008) in which neonatal mortality was primarily caused by pregnancy, difficult childbirth and congenital anomalies. However, for children up to one month, we estimated that increases in the total coliforms in the water supplied to households is associated with increased mortality of children in this age group. Our results suggest that an increase by 1 standard deviation in non-

standard total coliforms samples results in an increase of mortality per 1000 live births by 0.06 standard deviations in this age group in the same time period.[4] More importantly, even when children between one and four years of age and five and nine years of age were included, significant effects of water access were not observed for mortality, which suggests that this water access policy no longer appears to be a relevant factor for reducing infant mortality in Brazil for the period under study. Access to sewage services and sewage treatment (lagged) appear to reduce mortality among children between five and nine years of age and one and four years of age, respectively. We suggest that a 1 standard deviation increase in sewage treatment coverage in the two years prior will produce a decrease in the mortality of children by 0.22 standard deviations between one and four years of age per 1000 live births. However, a 1 standard deviation increase in sewage coverage in one prior period leads to a reduction in mortality rates by 0.28 standard deviations in children between five and nine years of age per 1000 live births. Population size and per capita income are positively associated with infant mortality, corroborating previous findings (Duchiade and Beltrão, 1992). Finally, regional trends and control functions were significant for most models, reinforcing the heterogeneity of the development stage for Brazilian regions and the need to use corrective functions for selection bias.

[4] To transform the results shown in Tables 5a to 8c into standard deviations, we divided the standard deviation of the explanatory variable by the standard deviation of the dependent variable and multiplied this figure by the coefficients. The standard deviation values of each variable are presented in Table 1. The standard errors, shown in parentheses in Tables 4a to 9, were obtained by bootstrapping.

Table 4a: Effect of Sanitation Indicators on Infant Deaths

Bias Corrected Model - Mortality indicators				
	1 month	**1 year**	**1-4 years**	**5-9 years**
	(1)	(2)	(3)	(4)
Water access (t)	0.0409	0.0151	-0.0268	-0.00869
	(0.035)	(0.024)	(0.044)	(0.029)
Water access (t-1)	0.0472	0.0382	0.0494	0.0221
	(0.045)	(0.036)	(0.041)	(0.026)
Water access (t-2)	-0.0511	-0.0511	-0.0274	-0.00310
	(0.053)	(0.035)	(0.062)	(0.037)
Sewage (t)	0.00741	-0.00360	0.00712	-0.00474
	(0.036)	(0.015)	(0.050)	(0.032)
Sewage (t-1)	-0.0138	-0.00227	-0.0249	-0.0594**
	(0.031)	(0.014)	(0.044)	(0.028)
Sewage (t-2)	-0.00290	0.00220	-0.0319	-0.0237
	(0.026)	(0.011)	(0.028)	(0.020)
Sewage treatment (t)	0.0225	0.00287	0.0567	0.0440
	(0.036)	(0.015)	(0.044)	(0.029)
Sewage treatment (t-1)	-0.00908	-0.000229	-0.0102	0.00998
	(0.029)	(0.014)	(0.028)	(0.018)
Sewage treatment (t-2)	0.0128	0.0102	-0.0419**	-0.0139
	(0.024)	(0.015)	(0.021)	(0.015)
Water Losses (t)	-0.0217	-0.00938	0.00568	0.00225
	(0.027)	(0.009)	(0.010)	(0.006)
Water Losses (t-1)	-0.000441	-0.0130	-0.0199	-0.0177
	(0.029)	(0.012)	(0.016)	(0.011)
Water Losses (t-2)	-0.0272	-3.41e-05	0.00193	0.00508
	(0.049)	(0.025)	(0.038)	(0.021)
chlorine (t)	-0.00184	0.0126	-0.00204	-0.00747
	(0.029)	(0.013)	(0.015)	(0.011)
chlorine (t-1)	-0.0308	-0.00793	-0.00648	0.00131
	(0.037)	(0.018)	(0.025)	(0.017)
chlorine (t-2)	0.0282	0.0161	0.00705	-0.00694
	(0.045)	(0.020)	(0.027)	(0.018)
turbidity (t)	-0.0219	-0.0330*	-0.0311	-0.00322
	(0.035)	(0.019)	(0.032)	(0.026)
turbidity (t-1)	-0.0308	-0.00793	-0.00648	0.00131
	(0.037)	(0.018)	(0.025)	(0.017)
turbidity (t-2)	0.0635*	0.0268	-0.0304	0.00367
	(0.036)	(0.016)	(0.032)	(0.023)
Total Coliforms (t)	0.0606**	0.0145	0.115	0.0669
	(0.027)	(0.013)	(0.084)	(0.054)
Total Coliforms (t-1)	0.0172	-0.0107	-0.00616	-0.00410
	(0.037)	(0.015)	(0.026)	(0.023)
Total Coliforms (t-2)	-0.0273	-0.0446	-0.0304	-0.00921
	(0.113)	(0.062)	(0.094)	(0.067)

*** p<0.01, ** p<0.05, * p<0.1

Table 4b: Effect of Sanitation Indicators on Infant Deaths (Cont'd)

Bias Corrected Model - Mortality indicators

	(1)	(2)	(3)	(4)
Regional trends				
Central-West	-2.754**	-0.598	0.945	0.544
	(1.406)	(0.592)	(0.814)	(0.584)
Northeast	-2.404**	-0.450	1.548**	0.819*
	(1.219)	(0.476)	(0.766)	(0.544)
North	-2.498	-1.421	10.56*	6.200*
	(1.824)	(0.942)	(5.400)	(3.556)
Southeast	-1.198	-0.370	0.366	0.236
	(1.051)	(0.418)	(0.807)	(0.592)
South	-1.662*	-0.370	-0.148	-0.0855
	(0.999)	(0.462)	(0.734)	(0.522)
Control Variables				
GDP per capita	7.61e-06	2.20e-05	0.000221***	0.000114***
	(0.000)	(0.000)	(0.000)	(0.000)
Population (log)	3.891	1.956	2.572**	1.773**
	(2.925)	(1.357)	(1.255)	(0.888)
Childhood education	1.630	1.797	2.462***	1.350
	(2.201)	(1.201)	(0.872)	(0.857)
Saude da Família´s program	1.192	0.400	0.210	0.0737
attendance	(0.791)	(0.374)	(0.305)	(0.212)
Immunization coverage	0.0325	-0.00682	0.0270	0.0274*
	(0.047)	(0.022)	(0.022)	(0.017)
Control Functions				
Current period (t)	11.64	-9.855	-13.86	-15.77**
	(20.281)	(11.952)	(12.854)	(8.864)
Previous period (t-1)	-7.644	-6.354	-49.62***	-20.30**
	(17.458)	(9.962)	(20.646)	(12.884)
Two lags period (t-2)	24.88	-3.588	-52.18***	-33.05***
	(23.537)	(12.417)	(19.220)	(12.936)
Three lags period (t-3)	67.74	67.74	67.74	67.74
	(39.861)	(15.330)	(30.417)	(17.284)
Observations	1,326	1,326	1,326	1,326
R-squared	0.025	0.023	0.126	0.099

*** p<0.01, ** p<0.05, * p<0.1

4.2- Sanitation and Hospitalizations

In the analysis of sanitation effects on hospitalizations of children per age group, our study is restricted (by DATASUS, the data source) to three subsamples: hospitalizations of children up to one year of age, hospitalizations of children between one to four years of age and hospitalizations of children between five to nine years of age. We also tested if sanitation can affect hospitalizations related to the occurrence of diarrhea, dysentery, hepatitis and ARI. The sample-bias-corrected three-lagged model is the only model presented here.

The results for children's hospitalizations are relatively similar when infant mortality is considered. Although the role of sanitation is significant, it is limited. Water quality is also important for children's health, and the increased incidence of coliforms in water used for consumption increased the number of hospitalizations of children up to one year of age. Our results suggest that an increase of 1 standard deviations in non-standard total coliforms samples implies an increase of 0.09 standard deviations in hospitalizations per 1000 live births in this age group in the same period. We found that the incidence of non-standard chlorine application appears to reduce the hospitalization of children between five and nine years of age, which was an unexpected result. Because the method of determining this indicator does not specify if the chlorine indicator is above or below standard levels, it is difficult to determine the cause of this unexpected result. However, we estimated that an increase of 1 standard deviations in access to water in two lag periods is related to the reduced morbidity of these children by -0.21 standard deviations. Compared with the relationship estimated for mortality, which was significant for children between five and nine years of age, access to sewage sanitation is only related to hospitalizations of children between one and four years of age. We estimated that a 1 standard deviation increase in access to sewage sanitation over the two prior periods was associated with reduced morbidity of 0.10 standard deviations in children one to four years of age in the two subsequent periods.

Our variable that captures childhood education is negatively related to hospitalizations, suggesting that increased access to education improves the indicator of hospitalizations in this age group. GDP is significant in all models but is only negative for hospitalizations of children between five and nine years of age. Finally, the trend of this hospitalization indicator does not differ among regions, and our control functions used to correct for selection bias are significant.

Thus, sanitation policies have a limited effect on the average infant mortality and morbidity rates for Brazil, which indicates that these policies should be investigated to determine whether they affect the country's regions at different development stages in different ways (Gamber-Rabindran, Khan and Timmins, 2007), which is explored in the next section. Below, we will discuss the results of columns (4) to (7) in Tables 5a and 5b, which are related to the association between sanitation policies and hospitalizations for diarrhea, dysentery, hepatitis and ARI.

Evidence that sanitation policies are associated with hospitalizations caused by diarrhea was not obtained here, which is a similar result to that of Sastry and Burgard (2005) and inconsistent with the results of Kremmer et al. (2010) for Kenya, and these policies are not associated with hospitalizations caused by hepatitis either. Hepatitis is an inflammation of the liver, which has several causes. Hepatitis A and E are transmitted by contaminated water and food, and this indicates a lack of sanitation caused by a lack of sewage treatment or lack of piped water. Because symptoms are only detected one month after contamination, the severity may increase, especially in children.

These two causes of hospitalization did not fit the model well, and for hospitalizations related to diarrhea and hepatitis, we found adjusted R^2 values lower than 0.04 and 0.072, respectively. The difficulty in fitting the model may have been caused by the low incidence of hospitalizations for

hepatitis and diarrhea in the 2003-2010 period, which is shown in panel 4b. In addition, only population was found to affect the two models jointly and negatively (reducing hospitalizations), and the incidence of vaccination reduces morbidity caused by diarrhea.

Access to water appears to be important for reducing hospitalizations caused by dysentery and ARI. Dysentery infections are spread by contaminated hands, food and water and are related to poor sanitation quality. The high spread of contamination via the hands increases the risk of the disease being diagnosed in children. Access to water and sewage treatment are extremely important factors for reducing hospitalizations caused by dysentery in the current period. We estimate that an increase of one percentage point in access to water and sewage treatment would reduce hospitalizations caused by dysentery by 0.033 and 0.0102, respectively, per 100,000 inhabitants over the same period, which indicates that a contemporaneous increase of 1 standard deviation in access to water and sewage treatment would decreases hospitalizations for dysentery by 0.19 and 0.08 standard deviations. Access to water is also associated with a reduction of 0.08 standard deviations in these hospitalizations in two subsequent periods. Finally, a different trend for this hospitalization indicator is observed in the north region, and our control functions used to correct selection bias are significant.

ARIs have a particularly strong effect on child populations in urban areas with poor hygiene, and they cause morbidity related to bronchiolitis, pneumonia, runny nose and adenoiditis, which affect the respiratory capacity. Access to sanitation can reduce these infection cases while improving the quality of hygiene of households. We found that water access policies had a strong ability to reduce hospitalizations related to ARI. In particular, we estimated that an increase of 1 standard deviation in access to water reduces hospitalizations for ARI within the same period by 0.11 standard deviations, and there is a corresponding increase of 0.10 standard deviations in the reduction of hospitalizations for ARI among the t-1 results. Thus, we observed a lagged effect of sanitation policy on this health indicator. The increase of one percentage point in access to infant education reduced hospitalizations for ARI by 1.2 per 100,000 inhabitants. GDP is positively associated with these hospitalizations and most likely indicates the municipality's development. This result reinforces the evidence showing that developed municipalities (higher per capita income and improved access to health policies) have increased hospitalizations for ARI, which is most likely because of higher environmental pollution levels. We also found evidence of different evolution trends of these hospitalizations among Brazilian regions. However, our sample bias corrected model was not significant in this case.

Table 5a: Effect of Sanitation Indicators on Hospitalizations

Bias Corrected Model - Morbidity indicators

	morb1	morb1a4	morb5a9	diarrhea	dysentery	hepatitis-B	acute respiratory infection
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Water access (t)	0.00939	0.00415	-0.0399	0.00638	-0.0333***	-0.000640	-0.0372**
	(0.040)	(0.062)	(0.039)	(0.014)	(0.010)	(0.001)	(0.017)
Water access (t-1)	-0.0416	-0.126*	0.0285	-0.00261	0.00383	-0.000735	-0.0345**
	(0.047)	(0.074)	(0.047)	(0.006)	(0.007)	(0.000)	(0.015)
Water access (t-2)	0.0594	-0.0892	-0.142**	-0.000734	-0.0136**	-0.000538	-0.0206
	(0.052)	(0.075)	(0.057)	(0.007)	(0.006)	(0.000)	(0.019)
Sewage (t)	0.00277	0.0243	-0.00612	0.00785	-0.00746	-0.000182	0.00962
	(0.040)	(0.055)	(0.046)	(0.007)	(0.005)	(0.000)	(0.013)
Sewage (t-1)	0.0135	-0.0133	0.0722*	0.0100*	-0.000904	8.74e-05	0.0172
	(0.035)	(0.062)	(0.038)	(0.005)	(0.004)	(0.000)	(0.012)
Sewage (t-2)	0.000275	-0.0794**	-0.0435	0.00664***	0.00119	9.17e-05	0.00338
	(0.026)	(0.034)	(0.031)	(0.003)	(0.003)	(0.000)	(0.009)
Sewage treatment (t)	0.0148	0.00486	-0.00378	0.00368	-0.0102**	6.14e-05	0.00501
	(0.041)	(0.048)	(0.028)	(0.005)	(0.005)	(0.000)	(0.010)
Sewage treatment (t-1)	0.0362	-0.00447	-0.0131	0.00231	0.000728	-9.65e-05	0.0160
	(0.038)	(0.062)	(0.034)	(0.004)	(0.004)	(0.000)	(0.010)
Sewage treatment (t-2)	0.0667*	0.0570	-0.00324	-0.00262	-0.00106	0.000353	0.00786
	(0.034)	(0.042)	(0.039)	(0.003)	(0.003)	(0.000)	(0.011)
Water Losses (t)	0.0159	0.0488	0.0553	0.00117	0.00244	0.000387	-0.000396
	(0.032)	(0.053)	(0.055)	(0.002)	(0.003)	(0.000)	(0.007)
Water Losses (t-1)	0.00320	0.0380	0.0397	-0.00103	-0.00101	0.000564	0.00199
	(0.033)	(0.052)	(0.051)	(0.004)	(0.004)	(0.000)	(0.009)
Water Losses (t-2)	-0.0409	0.0575	-0.0418	0.00283	-0.00585	-0.000437	-0.0352*
	(0.047)	(0.072)	(0.060)	(0.005)	(0.006)	(0.000)	(0.018)
chlorine (t)	0.0373	0.0126	-0.0946**	0.000744	0.000845	-2.48e-05	-9.00e-05
	(0.035)	(0.041)	(0.036)	(0.003)	(0.004)	(0.000)	(0.008)
chlorine (t-1)	0.0558	0.0131	-0.106**	-0.00619	0.000470	-0.000166	-0.00937
	(0.040)	(0.059)	(0.045)	(0.005)	(0.007)	(0.000)	(0.013)
chlorine (t-2)	-0.0638	0.115	-0.126**	-0.00978	0.0180	-0.000107	0.0132
	(0.042)	(0.079)	(0.059)	(0.010)	(0.013)	(0.000)	(0.019)
turbidity (t)	0.0142	0.0411	-0.0563	-0.00535	-0.00273	8.40e-05	-0.00488
	(0.038)	(0.055)	(0.043)	(0.005)	(0.005)	(0.000)	(0.013)
turbidity (t-1)	0.0558	0.0131	-0.106**	-0.00619	0.000470	-0.000166	-0.00937
	(0.040)	(0.059)	(0.045)	(0.005)	(0.007)	(0.000)	(0.013)
turbidity (t-2)	-0.0501	-0.180***	-0.149***	-0.00435	-0.00275	0.000685*	-0.00489
	(0.043)	(0.056)	(0.052)	(0.004)	(0.005)	(0.000)	(0.012)
Total Coliforms (t)	0.0978***	0.118*	0.0464	0.00540	-0.00349	0.000944	0.0192
	(0.037)	(0.068)	(0.039)	(0.008)	(0.009)	(0.001)	(0.016)
Total Coliforms (t-1)	-0.00111	-0.0126	-0.0266	0.00340	-0.00860	-0.000440	-0.000286
	(0.033)	(0.048)	(0.037)	(0.004)	(0.005)	(0.000)	(0.012)
Total Coliforms (t-2)	-0.161	0.0528	0.100	-0.00990	-0.00826	0.00241	-0.00408
	(0.141)	(0.228)	(0.190)	(0.017)	(0.023)	(0.002)	(0.046)

*** p<0.01, ** p<0.05, * p<0.1

Table 5b: Effect of Sanitation Indicators on Hospitalizations (column headings as in Table 5a)

Bias Corrected Model - Morbidity indicators

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Regional trends							
Central-West	-1.016	-0.586	1.460	-0.130	-0.0304	-0.00336	-0.704
	(1.124)	(1.915)	(1.635)	(0.245)	(0.230)	(0.011)	(0.463)
Northeast	0.357	-1.884	0.962	-0.194	-0.201	0.000873	-0.160
	(0.735)	(1.277)	(0.919)	(0.202)	(0.169)	(0.009)	(0.279)
North	1.285	-2.361	1.258	0.314	0.637**	0.00998	1.244*
	(1.637)	(2.860)	(2.337)	(0.350)	(0.336)	(0.043)	(0.655)
Southeast	0.201	0.338	1.417	-0.166	0.0655	-0.00818	-0.451*
	(0.800)	(1.104)	(1.081)	(0.208)	(0.164)	(0.010)	(0.259)
South	-0.269	0.130	0.402	-0.0735	-0.162	-0.00500	-0.523**
	(0.843)	(1.130)	(1.130)	(0.203)	(0.164)	(0.011)	(0.245)
Control Variables							
GDP per capita	0.000209***	0.000144***	-0.000101**	-6.55e-07	-5.20e-09	1.40e-07	5.18e-05***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Population (log)	-5.919**	-4.909	-0.607	-3.936***	-12.58***	-0.0761**	-37.42***
	(2.652)	(3.364)	(2.500)	(1.003)	(1.361)	(0.037)	(3.138)
Childhood education	-3.763*	-7.703***	-6.782***	-0.340	0.218	0.0574*	-1.217*
	(1.936)	(2.409)	(2.169)	(0.349)	(0.284)	(0.030)	(0.623)
Saude da Família´s	0.216	-0.289	-0.578	0.111	0.276	-0.00515	0.526
program attendance	(0.631)	(0.904)	(0.700)	(0.101)	(0.174)	(0.011)	(0.366)
Immunization coverage	-0.000561	0.00560	-0.188**	-0.0219**	-0.00193	0.000337	-0.00381
	(0.053)	(0.077)	(0.076)	(0.009)	(0.008)	(0.001)	(0.015)
Control Functions							
Current period (t)	4.695	-56.65**	71.50***	1.480	6.606*	-0.265	7.563
	(18.022)	(29.311)	(24.769)	(4.872)	(3.440)	(0.161)	(6.503)
Previous period (t-1)	30.18*	85.81***	-54.65**	6.243	-7.637***	-0.0213	6.710
	(17.129)	(29.645)	(29.726)	(3.959)	(3.440)	(0.161)	(6.503)
Two lags period (t-2)	-6.656	33.34	14.46	-3.367	7.250**	-0.0656	-3.698
	(21.374)	(28.698)	(21.214)	(5.930)	(3.383)	(0.220)	(6.321)
Three lags period (t-3)	67.74	67.74	67.74	67.74	67.74	67.74	67.74
	(25.473)	(28.681)	(36.613)	(6.017)	(3.642)	(0.231)	(9.185)
Observations	1,326	1,326	1,326	1,326	1,326	1,326	1,326
R-squared	0.098	0.072	0.076	0.071	0.440	0.037	0.564

*** p<0.01, ** p<0.05, * p<0.1

5. Epidemiological Transition

In this section, we modified the model presented in section 4 to allow for different effects of the sanitation variables on health indicators depending on the epidemiological transition stage of the Brazilian municipality. Therefore, we ordered the municipalities according to each health indicator and created three groups for each indicator. The first group contains the municipalities in the first quartile of the distribution, or the municipalities among the highest 25% for health indicators in that year; the second group corresponds to the 2nd quartile; and the last group contains municipalities that are among the lowest 25% for health indicators in that year. We observed that municipalities rated as having the 25% lowest health indicators in one year could

have in a different ranking in another year.[5] Thus, we used sanitation indicators interacting with binary variables as explanatory variables in this model to indicate whether municipalities belong to each of the groups. Hence, the effect of sanitation on health may be different for each of these four groups.

The results of this new exercise are listed in Tables 6 and 7[6]. Table 6 shows the results for the number obtained per age group, whereas Tables 7a and 7b show the results for hospitalizations.

The information in Table 6 supports the current limited role of sanitation on mortality, and limited results are presented that confirm the epidemiological transition hypothesis, where the relationship between sanitation and health indicators should be stronger for municipalities with worse health indicators.

The epidemiological transition hypothesis is supported by the effects of sanitation on the mortality of children up to one year of age and turbidity in the mortality of children up to one month of age, thus reinforcing the hypothesis of the heterogeneous impact of sanitation in Brazil found in Gamper-Rabrindan, Khan and Timmins (2007). For the first case, a mortality effect was not observed in municipalities with the best sanitation indicators, an intermediate mortality effect was observed for municipalities with median sanitation indicators (reduction of 0.0336 in mortality per 1000 live births), and a much stronger mortality effect was observed for municipalities in the last quartile with the worst sanitation indicators (reduction of 0.0585 in mortality per 1000 live births), which indicates that a 1 standard deviation increase in sewage collection would reduce mortality by 0.237 standard deviations. As for the second case, water turbidity is associated with a lagged increase in mortality of children up to one month of age only for municipalities in the median quartiles (increase of 0.04 after the first year and another 0.04 for the second year), whereas for municipalities with the worst indicators of turbidity-related mortality, this effect presents an increase of 0.18 with two lagged periods. We observed again that sewage treatment reduces mortality of children between five and nine years of age but only has a significant effect in municipalities with median indicators.

[5] This model is referred to as variable ranking. The results for the municipalities with fixed epidemiological order in all models are given in Appendix A3.

[6] The estimated models in this section also include the same control variables as the previous models (population, GDP, early childhood education, and Family Health Program attendance), regional trends and control functions. Because we are interested in discussing the epidemiological transition in this section, we omitted the results related to these explanatory variables.

Table 6: Epidemiological Transition – Mortality

Bias Corrected Model - Mortality indicators - Mobile Rank												
	1 month			1 year			1-4 years			5-9 years		
	1st quartile	median quartiles	4th quartile	1st quartile	median quartiles	4th quartile	1st quartile	median quartile	4th quartile	1st quartile	median quartile	4th quartile
Water access (t)	-0.00914	-0.0104	0.124**	-0.0229	0.00304	0.104***	-0.0172	0.0107	-0.00953	-0.0218	-0.0371	0.00225
	(0.043)	(0.025)	(0.047)	(0.027)	(0.013)	(0.039)	(0.017)	(0.039)	(0.053)	(0.020)	(0.031)	(0.025)
Water access (t-1)	-0.0401	0.0192	0.0168	-0.0313	0.00360	0.0594	-0.0140	0.0669	-0.0518	0.0207	0.0443	-0.00190
	(0.045)	(0.022)	(0.067)	(0.040)	(0.015)	(0.041)	(0.018)	(0.054)	(0.055)	(0.020)	(0.035)	(0.021)
Water access (t-2)	-0.0177	-0.0130	-0.0505	-0.0116	-0.00929	-0.110***	-0.0342	-0.0946	0.0264	-0.0107	-0.00439	0.00404
	(0.035)	(0.026)	(0.051)	(0.034)	(0.018)	(0.040)	(0.021)	(0.060)	(0.049)	(0.019)	(0.036)	(0.031)
Sewage (t)	-0.0686*	0.00187	-0.0669	-0.000490	-0.0336***	-0.0585**	-0.0289	0.0763	0.0648	-0.0148	-0.0767*	0.00992
	(0.034)	(0.022)	(0.104)	(0.029)	(0.011)	(0.026)	(0.031)	(0.098)	(0.048)	(0.023)	(0.040)	(0.031)
Sewage (t-1)	0.0159	0.0151	0.163	0.00645	-0.00382	-0.0253	0.0326	-0.128	-0.0140	0.0273	0.0811*	-0.0389
	(0.032)	(0.019)	(0.109)	(0.026)	(0.010)	(0.033)	(0.043)	(0.087)	(0.036)	(0.024)	(0.042)	(0.024)
Sewage (t-2)	0.0414	0.0116	-0.0591	-0.0476*	-0.00272	0.0360*	-0.0134	0.0220	-0.0273	-0.00622	-0.0341**	0.00225
	(0.029)	(0.017)	(0.049)	(0.026)	(0.008)	(0.019)	(0.036)	(0.024)	(0.035)	(0.010)	(0.016)	(0.027)
Sewage treatment (t)	0.0433	0.0319	0.206**	0.0196	0.0300***	0.0692***	0.0443*	0.0144	0.0533	-0.0284	0.0329	0.0403
	(0.032)	(0.022)	(0.082)	(0.022)	(0.009)	(0.021)	(0.023)	(0.041)	(0.046)	(0.019)	(0.027)	(0.030)
Sewage treatment (t-1)	-0.0253	-0.0146	-0.148	-0.0308	-0.000776	-0.0541	0.0126	0.106**	-0.0110	0.0199	-0.0140	-0.00971
	(0.032)	(0.016)	(0.096)	(0.036)	(0.009)	(0.033)	(0.023)	(0.051)	(0.038)	(0.028)	(0.027)	(0.027)
Sewage treatment (t-2)	-0.0194	0.00882	0.00914	0.0255	0.00567	0.0464*	-0.00863	-0.113**	0.000327	-0.0107	-0.00169	-0.0171
	(0.029)	(0.014)	(0.066)	(0.026)	(0.008)	(0.024)	(0.019)	(0.047)	(0.028)	(0.013)	(0.017)	(0.014)
Water Losses (t)	-0.0364***	-0.0163	-0.0156	-0.0134*	0.00180	-0.00336	-0.00795	0.0594*	-0.0325*	-0.0659	0.0409	0.0580
	(0.013)	(0.013)	(0.017)	(0.007)	(0.006)	(0.014)	(0.006)	(0.033)	(0.019)	(0.048)	(0.038)	(0.048)
Water Losses (t-1)	-0.0192	-0.0190	0.00341	-0.00617	-0.000904	-0.00365	-0.0147	0.0646	-0.0619	0.0264	-0.147**	-0.0417
	(0.016)	(0.020)	(0.023)	(0.009)	(0.009)	(0.020)	(0.011)	(0.040)	(0.042)	(0.034)	(0.062)	(0.034)
Water Losses (t-2)	0.0463	0.00638	-0.00282	0.0685**	0.0163	-0.00332	0.00381	-0.151*	0.0976*	0.00637	0.0968*	-0.0103
	(0.046)	(0.026)	(0.060)	(0.032)	(0.013)	(0.030)	(0.026)	(0.075)	(0.052)	(0.017)	(0.055)	(0.021)
chlorine (t)	0.0232	0.00669	0.128*	0.0112	-0.00461	-0.00326	0.0145	0.0241	-0.00356	0.00910	-0.0629	-0.00964
	(0.026)	(0.020)	(0.073)	(0.018)	(0.010)	(0.016)	(0.016)	(0.042)	(0.029)	(0.014)	(0.055)	(0.012)
chlorine (t-1)	-0.0105	0.0237	-0.0817	-0.0107	-0.0177	-0.0278	0.0529**	0.0120	-0.00169	0.00766	0.0116	0.00528
	(0.055)	(0.028)	(0.088)	(0.024)	(0.013)	(0.017)	(0.023)	(0.030)	(0.028)	(0.013)	(0.042)	(0.017)
chlorine (t-2)	-0.137**	0.0257	-0.0587	-0.000174	-0.00114	-0.0169	0.0112	-0.0904*	0.0434	0.0180	-0.00946	-0.0206
	(0.064)	(0.027)	(0.067)	(0.024)	(0.014)	(0.023)	(0.026)	(0.049)	(0.034)	(0.021)	(0.043)	(0.018)
turbidity (t)	-0.0682	0.0194	-0.0682	-0.0361	-0.0142	-0.0361	-0.0162	-0.0517*	-0.0162	-0.0132	0.0125	-0.0132
	(0.085)	(0.027)	(0.085)	(0.027)	(0.010)	(0.027)	(0.037)	(0.029)	(0.037)	(0.024)	(0.043)	(0.024)
turbidity (t-1)	-0.0361	0.0406**	-0.0720	-0.147*	-0.00613	-0.0399*	-0.0156	-0.0395	0.0383	-0.0305	-0.0176	-0.0116
	(0.072)	(0.019)	(0.053)	(0.079)	(0.010)	(0.020)	(0.042)	(0.033)	(0.038)	(0.025)	(0.075)	(0.026)
turbidity (t-2)	0.108	0.0439**	0.187**	-0.0338	-0.00107	0.0444	0.00961	0.0270	-0.0439	0.0533**	0.0553	-0.00672
	(0.097)	(0.018)	(0.085)	(0.067)	(0.011)	(0.030)	(0.048)	(0.037)	(0.050)	(0.025)	(0.038)	(0.025)
Total Coliforms (t)	0.0502***	-0.00533	0.243*	-0.000167	0.0138	0.0496	0.0519***	-0.0524	0.231	-0.0687	0.0839	0.103
	(0.014)	(0.034)	(0.143)	(0.012)	(0.025)	(0.118)	(0.021)	(0.150)	(0.200)	(0.110)	(0.183)	(0.115)
Total Coliforms (t-1)	0.228	0.0708	0.0663	0.0759	0.0185	-0.0514	0.184	0.0963	0.0471	0.0118	0.0391	-0.00624
	(0.221)	(0.061)	(0.185)	(0.130)	(0.038)	(0.085)	(0.131)	(0.122)	(0.157)	(0.102)	(0.108)	(0.085)
Total Coliforms (t-2)	-0.0419	-0.0722	-0.336**	-0.00504	-0.0395	0.0184	-0.118	0.140	0.0318	-0.00844	0.000146	0.0206
	(0.226)	(0.069)	(0.157)	(0.138)	(0.040)	(0.094)	(0.139)	(0.100)	(0.102)	(0.095)	(0.083)	(0.064)

*** p<0.01, ** p<0.05, * p<0.1

With regard to hospitalizations per age (Table 7a), certain estimates are opposite to what was expected, such as the estimate for sewage treatment, which was positively associated with morbidity in children under one year with two lagged periods in municipalities with the worst indicators; however, the results generally appear to be consistent with what was found for the mean effect, which was a limited effect of sanitation policies on health and potential evidence of epidemiological transition.

We found weak evidence for an epidemiological transition when the association between the hospitalization of children under one year and access to sanitation was examined. This association is higher in municipalities with the worst indicators of sanitation-related mortality (reduction of 0.09 in two lagged periods). For municipalities in the median of this indicator, we estimated a negative association with sanitation-related mortality of approximately 0.06 (with one lagged period). For children between five and nine years of age, we also found that water access reduces hospitalization in this age group, and the effect is higher in municipalities with the worst indicators.

Finally, when the effects of sanitation policies on diseases are analyzed for the three quartiles, we note an absence of evidence in favor of epidemiological transition (see Table 7b). Similar to the results for the mean, we observed that only hospitalizations for certain diseases are systematically affected by sanitation policies. However, evidence is not available to support a greater effect of sanitation on hospitalizations for diseases for the 25% worst municipalities.

Table 7a: Epidemiological Transition – Morbidity by Age

Bias Corrected Model - Morbidity indicators - Mobile Rank

	morb1			morb1a4			morb5a9		
	1st quartile	median quartiles	4th quartile	1st quartile	median quartiles	4th quartile	1st quartile	median quartiles	4th quartile
Water access (t)	-0.111**	-0.0735*	0.0678*	-0.161**	-0.0979*	0.239***	-9.84e-05**	0.0102	0.0540
	(0.044)	(0.037)	(0.038)	(0.063)	(0.055)	(0.079)	(0.050)	(0.031)	(0.073)
Water access (t-1)	-0.0533	-0.0901**	0.0269	-0.100	-0.0334	-0.167	-0.100	0.0497	0.200**
	(0.050)	(0.035)	(0.042)	(0.076)	(0.056)	(0.111)	(0.064)	(0.034)	(0.096)
Water access (t-2)	0.00906	0.0758**	-0.0548	-0.00322	-0.0175	-0.0695	0.000378	-0.112***	-0.211**
	(0.050)	(0.037)	(0.051)	(0.066)	(0.058)	(0.096)	(0.051)	(0.043)	(0.082)
Sewage (t)	-0.0370	0.0323	0.0580	0.0741	0.0373	0.0520	0.0401	-0.0195	0.143**
	(0.036)	(0.030)	(0.067)	(0.060)	(0.051)	(0.117)	(0.047)	(0.042)	(0.070)
Sewage (t-1)	0.0804	-0.0673**	-0.00142	-0.0213	0.0416	0.0269	0.0126	-0.0139	-0.106
	(0.053)	(0.026)	(0.065)	(0.065)	(0.057)	(0.134)	(0.051)	(0.043)	(0.085)
Sewage (t-2)	-0.0525	0.0106	-0.0918**	0.0396	-0.0108	-0.0621	-0.0215	0.0291	0.0318
	(0.045)	(0.020)	(0.043)	(0.065)	(0.021)	(0.102)	(0.048)	(0.037)	(0.045)
Sewage treatment (t)	0.00506	0.0538*	-0.0144	-0.0962**	-0.0175	0.0537	-0.0266	0.0376	-0.227***
	(0.027)	(0.031)	(0.058)	(0.040)	(0.047)	(0.105)	(0.030)	(0.034)	(0.063)
Sewage treatment (t-1)	0.0226	0.0295	0.0748	-0.0124	-0.0544	-0.0125	-0.106**	-0.0306	0.255**
	(0.043)	(0.028)	(0.050)	(0.044)	(0.057)	(0.101)	(0.045)	(0.033)	(0.113)
Sewage treatment (t-2)	0.0343	0.0217	0.121***	0.0500	0.0526	0.0395	0.0227	-0.0512	-0.0708
	(0.048)	(0.027)	(0.043)	(0.045)	(0.036)	(0.065)	(0.055)	(0.034)	(0.086)
Water Losses (t)	-0.0134	0.0391*	0.0154	0.0212	0.0609	0.0682	-0.0132	0.0642	0.111***
	(0.013)	(0.022)	(0.020)	(0.022)	(0.058)	(0.053)	(0.036)	(0.059)	(0.040)
Water Losses (t-1)	-0.0108	0.00372	0.0267	0.0102	0.0419	0.0404	0.0212	0.0299	0.129**
	(0.024)	(0.023)	(0.025)	(0.033)	(0.047)	(0.079)	(0.049)	(0.046)	(0.049)
Water Losses (t-2)	0.0188	-0.0468	-0.0572	0.136*	0.0317	0.0789	0.0771	-0.0280	-0.116
	(0.047)	(0.033)	(0.050)	(0.072)	(0.048)	(0.108)	(0.064)	(0.042)	(0.102)
chlorine (t)	0.0983	0.0888***	0.0380	0.0742**	0.0781**	-0.0782	-0.0217	-0.00868	-0.141***
	(0.088)	(0.030)	(0.033)	(0.035)	(0.033)	(0.053)	(0.040)	(0.027)	(0.044)
chlorine (t-1)	0.164*	0.0265	0.0296	0.0640	0.0533	-0.0176	0.0130	-0.0404	-0.111**
	(0.091)	(0.041)	(0.036)	(0.047)	(0.041)	(0.066)	(0.038)	(0.044)	(0.052)
chlorine (t-2)	-0.0327	0.0376	0.0500	-0.0429	0.00450	0.171**	-0.0454	-0.0766	-0.0354
	(0.041)	(0.040)	(0.062)	(0.072)	(0.081)	(0.076)	(0.072)	(0.051)	(0.054)
turbidity (t)	0.0367	7.02e-05	0.0367	0.196	-0.101*	0.196	0.000800	-0.0255	0.000800
	(0.060)	(0.029)	(0.060)	(0.129)	(0.051)	(0.129)	(0.092)	(0.044)	(0.092)
turbidity (t-1)	0.0935**	-0.0493*	0.00174	-0.0471	0.0414	-0.193	-0.0229	-0.0520	0.181
	(0.040)	(0.029)	(0.072)	(0.040)	(0.053)	(0.143)	(0.034)	(0.042)	(0.122)
turbidity (t-2)	-0.0784*	-0.00140	-0.179	-0.172***	-0.125**	0.108	-0.108***	-0.0400	-0.363**
	(0.045)	(0.025)	(0.115)	(0.044)	(0.054)	(0.167)	(0.036)	(0.045)	(0.162)
Total Coliforms (t)	-0.329	0.145	0.0862***	0.643***	-0.140	0.00910	-0.0118	-0.0385	0.0371
	(0.264)	(0.101)	(0.027)	(0.221)	(0.212)	(0.104)	(0.197)	(0.065)	(0.062)
Total Coliforms (t-1)	0.311**	0.194	0.0847	-0.0753	0.0925	0.697*	0.00843	0.0155	-0.235
	(0.157)	(0.158)	(0.128)	(0.234)	(0.171)	(0.382)	(0.172)	(0.118)	(0.367)
Total Coliforms (t-2)	-0.154	-0.00528	-0.0609	-0.174	0.489**	-0.527	-0.219	-0.222	0.316
	(0.190)	(0.116)	(0.174)	(0.203)	(0.188)	(0.391)	(0.188)	(0.210)	(0.275)

*** p<0.01, ** p<0.05, * p<0.1

Table 7b: Epidemiological Transition – Morbidity Illness[7]

Bias Corrected Model - Morbidity indicators - Mobile Rank

	diarrhoea			dysentery			hepatitis			acute respiratory infection		
	1st quartile	median quartiles	4th quartile	1st quartile	median quartiles	4th quartile	1st quartile	median quartiles	4th quartile	1st quartile	median quartiles	4th quartile
Water access (t)	-3.56e-06	-0.00750	0.0488	3.41e-07	-0.0217***	-0.0161	9.39e-08	0.000973**	-0.000571	4.79e-05***	-0.0621***	0.0297
	(0.007)	(0.007)	(0.036)	(0.006)	(0.007)	(0.014)	(0.000)	(0.000)	(0.001)	(0.018)	(0.017)	(0.034)
Water access (t-1)	0.000877	0.00289	-0.0243	-0.00902	0.00316	0.0426***	-0.00152**	4.84e-05	-0.000663	-0.0200	-0.00606	-0.0443*
	(0.008)	(0.012)	(0.018)	(0.008)	(0.006)	(0.014)	(0.001)	(0.000)	(0.001)	(0.015)	(0.012)	(0.026)
Water access (t-2)	0.00234	0.00863	2.23e-05	0.00181	-0.00658	-0.0210	-3.90e-06	-0.000287	0.000684	-0.0185	-0.00946	-0.0321
	(0.011)	(0.009)	(0.012)	(0.006)	(0.007)	(0.013)	(0.000)	(0.000)	(0.001)	(0.016)	(0.014)	(0.041)
Sewage (t)	0.00877	0.00916	-0.0101	0.000287	-0.000338	-0.0358	0.000715	-0.000399	-0.000269	0.00488	0.0130	0.0690
	(0.006)	(0.006)	(0.023)	(0.004)	(0.005)	(0.025)	(0.000)	(0.000)	(0.000)	(0.012)	(0.014)	(0.061)
Sewage (t-1)	0.0143**	0.00736	0.0258	0.00323	-0.00186	-0.00279	-0.000805	0.000166	0.000120	0.0293**	0.00756	0.00799
	(0.007)	(0.005)	(0.024)	(0.003)	(0.004)	(0.022)	(0.001)	(0.000)	(0.000)	(0.012)	(0.011)	(0.078)
Sewage (t-2)	0.0117*	0.0139**	0.000820	0.00189	-0.000417	0.0216	0.000301	-4.26e-05	3.76e-05	0.0158	0.0214*	-0.0785
	(0.006)	(0.007)	(0.006)	(0.002)	(0.005)	(0.017)	(0.000)	(0.000)	(0.000)	(0.010)	(0.011)	(0.098)
Sewage treatment (t)	-0.00410	-0.00533	0.00859	-0.00128	-0.00439	-0.0233*	0.000430	0.000179	-0.000436	-0.00426	0.00911	-0.0549
	(0.003)	(0.004)	(0.013)	(0.003)	(0.005)	(0.013)	(0.000)	(0.000)	(0.000)	(0.010)	(0.010)	(0.033)
Sewage treatment (t-1)	-0.00447	-0.00240	0.00649	-0.00576*	0.00255	0.0408***	-8.79e-05	8.18e-05	-6.15e-05	-0.00109	0.00950	0.0864*
	(0.004)	(0.004)	(0.011)	(0.003)	(0.005)	(0.011)	(0.000)	(0.000)	(0.001)	(0.008)	(0.010)	(0.043)
Sewage treatment (t-2)	-0.00377	-0.00216	-0.00849	-0.00107	-0.00419	-0.00795	-0.000559	0.000340	0.00109***	-0.00331	-0.00194	0.0437
	(0.004)	(0.003)	(0.009)	(0.003)	(0.005)	(0.012)	(0.000)	(0.000)	(0.000)	(0.008)	(0.012)	(0.029)
Water Losses (t)	0.00241	0.000147	-0.00241	0.00223	9.22e-05	0.00303	0.000249	0.000749**	0.000283	-0.00157	0.00211	0.00355
	(0.002)	(0.002)	(0.005)	(0.002)	(0.006)	(0.005)	(0.000)	(0.000)	(0.000)	(0.008)	(0.009)	(0.008)
Water Losses (t-1)	0.00307	-0.00105	-0.0107*	0.00252	-0.000435	-0.0113	0.000105	-0.000464	0.000732	-0.0110	-0.00200	0.0149
	(0.002)	(0.004)	(0.006)	(0.003)	(0.005)	(0.007)	(0.000)	(0.000)	(0.000)	(0.009)	(0.010)	(0.013)
Water Losses (t-2)	0.00202	0.00488	0.0120	0.00552	0.000462	-0.0121	0.000139	0.000347	-0.000592	-0.0258*	-0.0443**	-0.0423
	(0.005)	(0.005)	(0.010)	(0.008)	(0.006)	(0.011)	(0.000)	(0.000)	(0.001)	(0.013)	(0.017)	(0.036)
chlorine (t)	0.000429	-0.00130	0.00797	0.0105***	0.00177	0.0174*	0.000321	0.000110	6.95e-05	0.00538	0.00980	-0.0107
	(0.003)	(0.004)	(0.013)	(0.004)	(0.005)	(0.009)	(0.000)	(0.000)	(0.000)	(0.013)	(0.009)	(0.012)
chlorine (t-1)	-0.00227	-0.00874	0.0149	0.0111**	0.00211	-0.0111	-0.000193	-0.000113	0.000384	0.0231	-0.0140	-0.0167
	(0.004)	(0.006)	(0.016)	(0.005)	(0.006)	(0.010)	(0.000)	(0.000)	(0.000)	(0.029)	(0.012)	(0.017)
chlorine (t-2)	-0.0110	-0.0211	-0.00675	0.00302	-0.000882	0.0721***	0.000834	-2.13e-05	-0.000711	-0.000409	-0.00538	0.0469**
	(0.008)	(0.024)	(0.011)	(0.006)	(0.006)	(0.015)	(0.001)	(0.000)	(0.001)	(0.019)	(0.016)	(0.023)
turbidity (t)	-0.0120	-0.0108*	-0.0120	-0.0107	-0.000332	-0.0107	-0.000119	-0.000359	-0.000119	0.0194	0.0169	0.0194
	(0.013)	(0.006)	(0.013)	(0.017)	(0.004)	(0.017)	(0.000)	(0.000)	(0.000)	(0.028)	(0.012)	(0.028)
turbidity (t-1)	0.00157	-0.00112	-0.00128	0.00122	-0.00265	-0.0354**	0.000481	-0.000436*	-0.000272	0.0177	-0.0165	-0.0257
	(0.004)	(0.005)	(0.014)	(0.007)	(0.004)	(0.017)	(0.001)	(0.000)	(0.000)	(0.013)	(0.010)	(0.044)
turbidity (t-2)	-0.00352	0.00603	0.00215	-0.00499	0.00379	-0.00104	-0.000730	-0.000426*	-0.000847*	0.00390	-0.00110	-0.0191
	(0.003)	(0.007)	(0.011)	(0.006)	(0.005)	(0.018)	(0.001)	(0.000)	(0.000)	(0.012)	(0.014)	(0.039)
Total Coliforms (t)	0.00381	0.0409*	0.0966*	-0.00707	-0.0339	0.00327	0.00653**	0.000602	-0.000221	-0.0352	-0.0464	0.0145
	(0.003)	(0.022)	(0.049)	(0.019)	(0.022)	(0.008)	(0.003)	(0.001)	(0.000)	(0.038)	(0.050)	(0.017)
Total Coliforms (t-1)	-0.00127	0.0336**	-0.0647*	-0.0103	0.00499	0.0719	-0.000360	0.00133	-0.00393	-0.122***	-0.0387	-0.00788
	(0.020)	(0.017)	(0.035)	(0.018)	(0.020)	(0.054)	(0.002)	(0.001)	(0.003)	(0.045)	(0.043)	(0.115)
Total Coliforms (t-2)	0.0110	0.0148	-0.00481	-0.00469	0.0240	-0.0182	-0.00172	0.000638	0.00611**	-0.0546	0.0492	0.0472
	(0.021)	(0.025)	(0.026)	(0.015)	(0.025)	(0.072)	(0.002)	(0.001)	(0.003)	(0.044)	(0.048)	(0.158)

*** p<0.01, ** p<0.05, * p<0.1

[7] Other control variables for the models are in the appendix.

6. Discussion

In this section, we discuss possible explanations for the limited effect of sanitation on Brazilian infant mortality indicators. As stated in the introduction, one of the possible explanations is that in the 2000s, access to water was already practically universal in Brazil and access to sanitation and sewage treatment improved slightly during the study period. In the descriptive data analysis (panels 1 and 2), we show that variation in access to water and sanitation was limited, whereas access to sewage treatment increased considerably in Brazilian regions. It is important to emphasize that this sewage treatment indicator represents the population percentage that has access to sewage. Thus, these graphs indicate that variations in sanitation indicators from 2003 to 2010 were not large and may be a possible explanation for the modest effects.

Another possible explanation is that sanitation effects differ among the Brazilian municipalities depending on their developmental stage. When we obtained the effect of sanitation for Brazil as a whole, we did not observe a high effect that should have occurred in municipalities with low health indicators. This explanation is not supported by the results of section 5, which indicate that weak evidence is available that Brazilian municipalities are in different epidemiological transition stages; therefore, the sanitation effects would differ among these municipalities.

Table 8a presents the results of the sample-bias corrected model for two additional explanatory variables: number of fetal deaths before birth and total number of fetal deaths. If sanitation indicators reduce fetal deaths, then their impact on infant mortality should be reduced because the effect of sanitation would occur before birth. This table shows a significant and negative effect of sewage treatment in two lagged periods on fetal deaths, indicating that this explanation is also possible.

Table 8a: Effect of Sanitation on Fetal Deaths

	fetal deaths (before birth)	Total fetal deaths
Water access (t)	-0.225	-0.285
	(0.296)	(0.338)
Water access (t-1)	-0.202	-0.259
	(0.424)	(0.456)
Water access (t-2)	-0.259	-0.307
	(0.324)	(0.344)
Sewage (t)	-0.520	-0.567
	(0.256)	(0.294)
Sewage (t-1)	-0.482	-0.540
	(0.340)	(0.388)
Sewage (t-2)	-0.368	-0.430
	(0.257)	(0.293)
Sewage treatment (t)	-0.254	-0.235
	(0.255)	(0.309)
Sewage treatment (t-1)	-0.194	-0.160
	(0.189)	(0.221)
Sewage treatment (t-2)	-0.611**	-0.642**
	(0.240)	(0.276)
Water Losses (t)	-0.0610	-0.0620
	(0.075)	(0.081)
Water Losses (t-1)	-0.0570	-0.0659
	(0.107)	(0.120)
Water Losses (t-2)	-0.256	-0.286
	(0.288)	(0.326)
chlorine (t)	-0.270**	-0.293**
	(0.133)	(0.147)
chlorine (t-1)	-0.372*	-0.402*
	(0.221)	(0.244)
chlorine (t-2)	-0.199	-0.199
	(0.184)	(0.202)
turbidity (t)	0.0495	0.0306
	(0.196)	(0.212)
turbidity (t-1)	-0.0304	-0.0285
	(0.237)	(0.259)
turbidity (t-2)	0.0226	-0.00585
	(0.200)	(0.224)
Total Coliforms (t)	0.217	0.226
	(0.414)	(0.449)
Total Coliforms (t-1)	0.449	0.433
	(1.355)	(1.463)
Total Coliforms (t-2)	-1.244	-1.334
	(0.920)	(1.001)

*** p<0.01, ** p<0.05, * p<0.1

Table 8b: Effect of Sanitation on Fetal Deaths (Cont'd)

Bias Corrected Model - Mortality indicators

	fetal deaths (before birth)	**Total fetal deaths**
Regional trends		
Central-West	38.42***	42.16***
	(5.942)	(6.623)
Northeast	67.64***	74.08***
	(8.331)	(9.078)
North	138.4***	154.7***
	(32.643)	(37.185)
Southeast	45.33***	50.94***
	(8.409)	(9.584)
South	33.47***	36.28***
	(5.039)	(5.696)
Control Variables		
GDP per capita	0.000247	0.000356
	(0.000)	(0.000)
Population (log)	-3.198	-4.366
	(10.326)	(11.446)
Childhood education	-0.480	-0.764
	(7.553)	(8.542)
Saude da Família´s	-3.008	-3.622
program attendance	(1.848)	(2.100)
Immunization coverage	-0.334	-0.330
	(0.181)	(0.205)
Control Functions		
Current period (t)	-406.6***	-447.1***
	(94.322)	(108.143)
Previous period (t-1)	-312.4***	-349.4***
	(96.197)	(107.832)
Two lags period (t-2)	-388.6***	-441.2***
	(97.626)	(108.320)
Three lags period (t-3)	67.74	67.74
	(319.048)	(353.851)
Observations	1,196	1,222
R-squared	0.231	0.225

*** p<0.01, ** p<0.05, * p<0.1

7. Conclusion

This articles identifies the effects of sanitation policies on infant health indicators and water-borne diseases for Brazilian municipalities. In addition, it explores the heterogeneity among developmental stages of Brazilian municipalities to identify the role of water access and quality and sewage sanitation on mortality and morbidity indicators in these municipalities. Thus, we produced a panel data model that controls for bias resulting from missing data caused by a lack of sanitation information for several Brazilian municipalities.

We found that sanitation policies have a limited effect on health indicators. In relation to the mortality of children up to one month of age, we estimated that increases in total coliforms in the water received in households is associated with increased mortality of children in this age group. Access to sewage systems and sewage treatment (lagged) appears to reduce mortality among children between five and nine years of age and one and four years of age, respectively.

The role of sanitation in children's hospitalizations is significant and limited, and water quality is also important for children's health. Increases in the incidence of coliforms in water used for consumption increases the number of hospitalizations of children aged up to one year. We found that for hospitalizations of children between five and nine years of age, an increase in the size of the population with access to water is related to a decrease in their morbidity. Access to sewage sanitation is only related to hospitalizations of children between one and four years of age. We found no evidence that sanitation policies are associated with hospitalizations caused by diarrhea or hepatitis. In addition, access to water and sewage treatment reduce hospitalizations because of dysentery, and a strong effect was observed for water access policies on the reduction of hospitalizations for ARI.

Only weak evidence corroborated that Brazilian municipalities are in different epidemiological transition stages. The only association between sewage sanitation and mortality and hospitalizations of children under one year of age occurred in municipalities that have the worst indicator of sanitation-related mortality. Worsened turbidity and mortality of children under one year of age also have a stronger association in municipalities with the worst indicators. The non-standard chlorine indicator and morbidity in children between one and four years of age are also consistently associated with this transition. For the other variables, evidence was not observed to support the hypothesis that Brazilian municipalities are in different epidemiological transition stages.

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Appendix A1: First Stage of Bias Correction

In this appendix we present the results of the first step of the procedure used to correct for bias caused by attrition. In this step, we estimate the factors related to the probability of a municipality reporting information in each of the sample periods. Because our reference period is 2003, we have no information from previous years to predict the probability of the municipality reporting information in 2003.

Table A1: Probability of Municipalities Reporting Information to the SNIS

Variables	s2004	s2005	s2006	s2007	s2008	s2009	s2010
Water access (t-1)	0.00433	0.00975	-0.0178	0.00102	0.00521	0.0185	-0.0565
	(0.00346)	(0.106)	(0.0234)	(0.0112)	(0.00679)	(0.0128)	(0.0397)
Sewage (t-1)	0.00490	-0.0289	-0.00675	-0.00166	-0.00497	0.00521	-0.00209
	(0.00333)	(0.0313)	(0.00770)	(0.00586)	(0.00373)	(0.00755)	(0.00983)
GDP per capita (t-1)	0.0114	-0.210	-0.0273	-0.0460	0.00952	-0.00267	-9.19e-06
	(0.0198)	(1.106)	(0.0244)	(0.0352)	(0.0156)	(0.0268)	(2.72e-05)
Population (log) (t-1)	0.0975	12.39	-8.840	-11.01*	0.576	1.065	-5.654
	(0.0821)	(12.85)	(9.185)	(6.084)	(0.696)	(1.235)	(16.20)
Childhood education (t-1)	0.311	5.194	0.725	0.358	0.304	1.088**	-0.102
	(0.264)	(3.641)	(1.101)	(0.476)	(0.229)	(0.495)	(0.707)
Saude da Família´s program	-0.122	-0.760	-0.665	0.400	0.0185	0.214	1.096
attendance (t-1)	(0.264)	(2.822)	(0.914)	(0.646)	(0.271)	(0.436)	(0.668)
Immunization coverage (t-1)	-0.000438	0.125	-0.0464*	0.000253	-0.0166**	0.0230	-0.00424
	(0.00920)	(0.0895)	(0.0271)	(0.0104)	(0.00722)	(0.0150)	(0.0190)
Water acess (t-2)		-0.0357	0.0322	0.00477	-0.00820	-0.0363***	0.0231
		(0.107)	(0.0237)	(0.0111)	(0.00683)	(0.0135)	(0.0371)
Sewage (t-2)		0.0202	0.00944	0.00579	0.00614	-0.0163**	-0.00567
		(0.0269)	(0.00932)	(0.00619)	(0.00383)	(0.00759)	(0.00977)
GDP per capita (t-2)		1.001	0.0350	0.0419	-0.0161	0.000454	0.0134
		(1.355)	(0.0376)	(0.0397)	(0.0171)	(0.0295)	(0.0337)
Population (log) (t-2)		-11.98	8.583	11.17*	-0.499	-0.931	5.819
		(12.93)	(9.195)	(6.110)	(0.694)	(1.226)	(16.24)
Childhood education (t-2)		-4.109	-0.744	-0.295	-0.315	-0.452	0.230
		(2.815)	(1.025)	(0.430)	(0.234)	(0.429)	(0.678)
Saude da Família´s program		-2.299	0.553	-0.668	-0.313	-0.503	-1.550**
attendance (t-2)		(3.418)	(0.853)	(0.634)	(0.312)	(0.387)	(0.736)
Immunization coverage (t-2)		-0.110	0.0262	-0.00613	0.00906	0.0103	0.00621
		(0.0692)	(0.0240)	(0.0123)	(0.00775)	(0.0146)	(0.0213)
Constant	0.644	-2.129	6.213***	1.065	2.513***	0.296	4.555*
	(1.316)	(6.154)	(1.939)	(1.431)	(0.861)	(1.732)	(2.452)
Observations	2,552	2,002	4,080	4,170	4,312	3,231	2,168

*** p<0.01, ** p<0.05, * p<0.1

Appendix A2: Models without bias correction

This section contains the results of the fixed effect panel model with sanitation variables lagged for two periods but without bias correction. The results of Tables A2a and A2b indicate a moderate effect of sanitation on health and often with a sign opposite to what was expected. This opposite sign may be related to the bias associated with the problem of missing sanitation data along the data panel.

Table A2a: Effect of Sanitation on Infant Deaths

UnCorrected Model - Mortality indicators				
	1 month	**1 year**	**1-4 years**	**5-9 years**
Water access (t)	0.0496	-0.00392	0.00145	0.0121
	(0.0540)	(0.0292)	(0.0249)	(0.0195)
Water access (t-1)	0.0345	0.0599*	0.0243	0.0206
	(0.0583)	(0.0316)	(0.0269)	(0.0211)
Water access (t-2)	0.0472	-0.0669**	0.00808	-0.0153
	(0.0536)	(0.0290)	(0.0247)	(0.0194)
Sewage (t)	-0.0143	0.000196	-0.0166	-0.0240
	(0.0455)	(0.0247)	(0.0210)	(0.0165)
Sewage (t-1)	0.00697	0.0173	-0.00579	-0.0159
	(0.0408)	(0.0221)	(0.0188)	(0.0148)
Sewage (t-2)	-1.50e-05	0.00109	-0.00994	-0.0179
	(0.0384)	(0.0208)	(0.0177)	(0.0139)
Sewage treatment (t)	0.0437	0.00615	0.0216	0.0149
	(0.0409)	(0.0222)	(0.0189)	(0.0148)
Sewage treatment (t-1)	-0.0236	-0.00144	-0.0143	-0.0155
	(0.0403)	(0.0218)	(0.0186)	(0.0146)
Sewage treatment (t-2)	0.0206	0.00801	-0.00773	0.0107
	(0.0373)	(0.0202)	(0.0172)	(0.0135)
Water Losses (t)	-0.0359	-0.00128	0.0105	0.00472
	(0.0299)	(0.0162)	(0.0137)	(0.0108)
Water Losses (t-1)	0.00230	-0.0187	-0.0222	-0.00100
	(0.0299)	(0.0162)	(0.0138)	(0.0108)
Water Losses (t-2)	0.0306	0.0134	0.0175	0.0104
	(0.0338)	(0.0183)	(0.0155)	(0.0122)
chlorine (t)	-0.0331	-0.0216	0.0180	0.00352
	(0.0558)	(0.0302)	(0.0257)	(0.0202)
chlorine (t-1)	-0.00588	-0.00353	0.00347	0.00389
	(0.0542)	(0.0293)	(0.0250)	(0.0196)
chlorine (t-2)	0.0228	0.0172	0.0386	0.00994
	(0.0709)	(0.0384)	(0.0327)	(0.0257)
turbidity (t)	-0.00188	-0.0305	-0.0145	0.00750
	(0.0640)	(0.0346)	(0.0295)	(0.0232)
turbidity (t-1)	-0.00588	-0.00353	0.00347	0.00389
	(0.0542)	(0.0293)	(0.0250)	(0.0196)
turbidity (t-2)	-0.0171	0.0148	-0.0285	-0.0102
	(0.0660)	(0.0357)	(0.0304)	(0.0239)
Total Coliforms (t)	0.00355	-0.0193	0.0591	0.0531
	(0.115)	(0.0623)	(0.0530)	(0.0416)
Total Coliforms (t-1)	0.00515	-0.000640	0.0194	0.000367
	(0.0654)	(0.0354)	(0.0301)	(0.0237)
Total Coliforms (t-2)	0.0136	-0.0508	-0.0194	-0.0209
	(0.123)	(0.0668)	(0.0568)	(0.0447)

*** p<0.01, ** p<0.05, * p<0.1

Table A2a: Effect of Sanitation on Infant Deaths (Cont'd)

UnCorrected Model - Mortality indicators

	1 month	1 year	1-4 years	5-9 years
Regional trends				
Central-West	-0.714	-0.380	0.139	0.0892
	(0.643)	(0.348)	(0.296)	(0.233)
Northeast	-0.374	-0.188	0.326	0.0494
	(0.548)	(0.297)	(0.252)	(0.198)
North	-2.440	-1.370	2.336***	1.526**
	(1.649)	(0.893)	(0.759)	(0.597)
Southeast	-0.549	-0.327	0.0801	-0.112
	(0.388)	(0.210)	(0.179)	(0.141)
South	-0.275	-0.234	-0.240	-0.173
	(0.375)	(0.203)	(0.173)	(0.136)
Control Variables				
GDP per capita	1.45e-05	3.63e-05*	4.36e-05***	3.57e-05***
	(3.61e-05)	(1.95e-05)	(1.66e-05)	(1.31e-05)
Population (log)	4.080	0.340	1.770	1.161
	(5.008)	(2.711)	(2.306)	(1.813)
Childhood educatio	0.821	-0.121	-0.0965	0.505
	(1.713)	(0.927)	(0.789)	(0.620)
Saude da Família´s	0.653	0.398	0.0600	-0.108
program	(1.186)	(0.642)	(0.546)	(0.429)
Immunization cover	-0.0600	-0.0517**	0.0470**	0.0118
	(0.0450)	(0.0243)	(0.0207)	(0.0163)
Observations	1,093	1,093	1,093	1,093
R-squared	0.005	0.008	0.019	0.014

*** p<0.01, ** p<0.05, * p<0.1

Table A2b: Effect of Sanitation on Hospitalizations

UnCorrected Model - Morbidity indicators

	morb1	morb1a4	morb5a9	diarrhea	dysentery	hepatitis	IRA
Water access (t)	0.0431	-0.0474	-0.0875	0.0122*	-0.0299***	-0.000610	-0.0237
	(0.0575)	(0.0816)	(0.0676)	(0.00641)	(0.00624)	(0.000497)	(0.0155)
Water access (t-1)	-0.110*	-0.105	0.0838	-0.00697	0.00293	-0.000260	-0.0376**
	(0.0621)	(0.0882)	(0.0731)	(0.00693)	(0.00674)	(0.000537)	(0.0168)
Water access (t-2)	0.0208	0.0728	-0.0560	0.000608	-0.000717	0.000699	0.0116
	(0.0571)	(0.0811)	(0.0672)	(0.00637)	(0.00619)	(0.000493)	(0.0154)
Sewage (t)	0.0231	0.0241	-0.0411	0.00173	0.00142	-0.000314	-0.0107
	(0.0485)	(0.0689)	(0.0571)	(0.00541)	(0.00526)	(0.000419)	(0.0131)
Sewage (t-1)	0.0253	0.0165	0.0123	0.00667	0.00276	-0.000190	0.00964
	(0.0434)	(0.0617)	(0.0511)	(0.00485)	(0.00471)	(0.000375)	(0.0117)
Sewage (t-2)	0.00480	0.00872	-0.0169	0.00251	0.00657	-9.47e-06	0.00586
	(0.0409)	(0.0581)	(0.0482)	(0.00457)	(0.00444)	(0.000354)	(0.0111)
Sewage treatment (t)	0.0306	0.0303	0.0271	0.000164	-0.00158	-8.75e-05	-0.000638
	(0.0436)	(0.0619)	(0.0513)	(0.00486)	(0.00473)	(0.000377)	(0.0118)
Sewage treatment (t-1)	0.0536	0.0722	0.0516	-0.00179	0.00478	0.000294	0.0150
	(0.0429)	(0.0609)	(0.0505)	(0.00479)	(0.00466)	(0.000371)	(0.0116)
Sewage treatment (t-2)	0.0246	-0.0133	-0.0338	-0.00165	0.000711	-4.40e-05	-0.0134
	(0.0397)	(0.0564)	(0.0467)	(0.00443)	(0.00431)	(0.000343)	(0.0107)
Water Losses (t)	-0.0158	0.0635	0.0908**	-0.00182	-0.00112	0.000274	-0.00497
	(0.0318)	(0.0451)	(0.0374)	(0.00355)	(0.00345)	(0.000275)	(0.00859)
Water Losses (t-1)	-0.0141	0.0501	0.0155	-0.00339	0.00297	0.000217	0.00104
	(0.0318)	(0.0452)	(0.0374)	(0.00355)	(0.00345)	(0.000275)	(0.00859)
Water Losses (t-2)	-0.0317	-0.0486	-0.0381	0.00467	-0.00358	-2.92e-05	-0.00804
	(0.0359)	(0.0511)	(0.0423)	(0.00401)	(0.00390)	(0.000311)	(0.00971)
chlorine (t)	0.00655	-0.00578	-0.153**	-0.00831	-0.00489	-0.000225	-0.0127
	(0.0594)	(0.0844)	(0.0700)	(0.00663)	(0.00645)	(0.000514)	(0.0161)
chlorine (t-1)	0.00159	0.00207	-0.0282	-0.00292	0.00186	-2.50e-05	0.00145
	(0.0577)	(0.0820)	(0.0679)	(0.00644)	(0.00627)	(0.000499)	(0.0156)
chlorine (t-2)	-0.0904	0.0658	-0.0629	0.00732	0.00526	9.49e-05	0.00491
	(0.0755)	(0.107)	(0.0889)	(0.00843)	(0.00820)	(0.000653)	(0.0204)
turbidity (t)	0.0243	0.0651	-0.0556	-0.00768	0.00706	-5.09e-05	-0.000934
	(0.0681)	(0.0968)	(0.0802)	(0.00760)	(0.00740)	(0.000589)	(0.0184)
turbidity (t-1)	0.00159	0.00207	-0.0282	-0.00292	0.00186	-2.50e-05	0.00145
	(0.0577)	(0.0820)	(0.0679)	(0.00644)	(0.00627)	(0.000499)	(0.0156)
turbidity (t-2)	-0.0482	-0.0466	-0.0834	0.00140	-0.00543	-0.000446	-0.00195
	(0.0703)	(0.0998)	(0.0827)	(0.00784)	(0.00763)	(0.000607)	(0.0190)
Total Coliforms (t)	0.0334	0.0407	0.0479	0.00784	-0.0134	0.000962	-0.0353
	(0.123)	(0.174)	(0.144)	(0.0137)	(0.0133)	(0.00106)	(0.0331)
Total Coliforms (t-1)	-0.0196	-0.114	-0.0542	0.00540	-0.0150**	-0.000454	-0.000424
	(0.0696)	(0.0989)	(0.0820)	(0.00777)	(0.00756)	(0.000602)	(0.0188)
Total Coliforms (t-2)	0.0276	0.114	0.0507	-0.00821	-0.00914	0.000396	-0.00785
	(0.131)	(0.187)	(0.155)	(0.0147)	(0.0143)	(0.00114)	(0.0355)

*** p<0.01, ** p<0.05, * p<0.1

Table A2b: Effect of Sanitation on Hospitalizations (Cont'd)

UnCorrected Model - Morbidity indicators

	morb1	morb1a4	morb5a9	diarrhoea	dysentery	hepatitis	IRA
Regional trends							
Central-West	-0.622	0.750	1.082	0.0581	0.248***	-0.000238	-0.199
	(0.685)	(0.972)	(0.806)	(0.0764)	(0.0743)	(0.00592)	(0.185)
Northeast	0.225	-0.288	0.373	-0.00390	0.0422	-0.000842	0.249
	(0.583)	(0.828)	(0.686)	(0.0651)	(0.0633)	(0.00504)	(0.158)
North	0.876	2.372	-1.246	0.111	0.468**	0.0219	0.650
	(1.756)	(2.494)	(2.066)	(0.196)	(0.191)	(0.0152)	(0.474)
Southeast	-0.336	-0.513	1.320***	0.0320	0.0607	-0.00910**	-0.000145
	(0.414)	(0.588)	(0.487)	(0.0462)	(0.0449)	(0.00358)	(0.112)
South	-0.173	-0.192	0.737	-0.0141	0.0132	-0.000530	-0.102
	(0.400)	(0.568)	(0.470)	(0.0446)	(0.0434)	(0.00346)	(0.108)
Control Variables							
GDP per capita	0.000155***	0.000239***	0.000180**	5.85e-06	1.79e-06	8.23e-07**	5.98e-05***
	(3.84e-05)	(5.46e-05)	(4.52e-05)	(4.29e-06)	(4.17e-06)	(3.32e-07)	(1.04e-05)
Population (log)	-4.139	-9.149	-3.957	-2.760***	-8.273***	-0.106**	-26.58***
	(5.332)	(7.574)	(6.274)	(0.595)	(0.579)	(0.0461)	(1.441)
Childhood educatio	-5.885***	-11.44***	-8.156***	-0.189	-0.0541	0.0374**	-2.249***
	(1.823)	(2.590)	(2.146)	(0.204)	(0.198)	(0.0158)	(0.493)
Saude da Família´s	0.174	-2.022	-1.532	0.229	0.680***	-0.00217	1.478***
program	(1.263)	(1.794)	(1.486)	(0.141)	(0.137)	(0.0109)	(0.341)
Immunization cover	0.116**	0.0601	-0.181***	-0.00554	-0.0187***	0.000836**	0.0325**
	(0.0479)	(0.0680)	(0.0563)	(0.00534)	(0.00520)	(0.000414)	(0.0129)
Observations	1,093	1,093	1,093	1,092	1,093	1,092	1,092
R-squared	0.022	0.022	0.024	0.021	0.119	0.014	0.176

*** p<0.01, ** p<0.05, * p<0.1

Appendix A3: Fixed order models

In this section, we present the results for the models used to investigate the epidemiological transition, and the municipalities are ordered according to their health indicators in 2010; this order is maintained over the years. The results of this new approach show the modest impact of sanitation indicators on health indicators.

Table A3a: Epidemiological Transition – Mortality

Bias Corrected Model - Mortality indicators - Fixed Rank

	1 month			**1 year**			**1-4 years**			**5-9 years**		
	1st quartile	median quartile	4th quartile	1st quartile	median quartile	4th quartile	1st quartile	median quartile	4th quartile	1st quartile	median quartile	4th quartile
Water access (t)	0.184	0.0122	-0.0671	0.0978	0.00151	-0.00569	-0.0548	0.00104	-0.0715	-0.000240	-	-0.00846
	(0.115)	(0.046)	(0.094)	.1028169	.016112	.040987	(0.035)	(0.037)	(0.101)	(0.028)	-	(0.050)
Water access (t-1)	-0.113	0.000471	0.0159	-0.130**	0.0150	0.0108	0.00582	0.184***	0.0462	0.0154	-	0.0149
	(0.102)	(0.048)	(0.107)	.0639898	.0198168	.0383992	(0.034)	(0.065)	(0.064)	(0.031)	-	(0.040)
Water access (t-2)	0.105	-0.0551	-0.163	-0.143	-0.00829	-0.0407	-0.0753*	-0.118**	0.0422	0.00895	-	-0.0118
	(0.133)	(0.064)	(0.102)	.1291886	.0245455	.0422888	(0.042)	(0.055)	(0.112)	(0.026)	-	(0.059)
Sewage (t)	-0.0205	0.0347	0.000830	-0.0644	-0.00373	-0.0221	0.0237	-0.109	0.0183	-0.0167	-	-0.000201
	(0.092)	(0.035)	(0.225)	.0579568	.0146902	.0436008	(0.028)	(0.067)	(0.089)	(0.018)	-	(0.055)
Sewage (t-1)	-0.113	-0.0260	0.235*	-0.130**	0.00714	0.0446	0.00582	0.0623	-0.0796	-0.0189	-	-0.0956
	(0.102)	(0.029)	(0.135)	.0639898	.0151169	.0317615	(0.034)	(0.097)	(0.101)	(0.017)	-	(0.061)
Sewage (t-2)	-0.0537	0.0343	0.0223	-0.00479	3.10e-06	-0.00674	-0.0314*	0.0662	-0.0539	0.00251	-	-0.0490
	(0.057)	(0.024)	(0.148)	.0840392	.0101767	.0321228	(0.017)	(0.045)	(0.056)	(0.009)	-	(0.035)
Sewage treatment (t)	-0.0162	-0.00340	0.107	-0.0320	-0.0106	0.0436	-0.0298	-0.0207	0.150	-0.0110	-	0.0858
	(0.076)	(0.040)	(0.187)	.0484222	.015539	.0461432	(0.024)	(0.026)	(0.102)	(0.013)	-	(0.058)
Sewage treatment (t-1)	-0.00644	-0.0390	0.0685	0.0756	-0.0146	0.0157	-0.00574	-0.0132	-0.0196	-0.0118		0.0103
	(0.102)	(0.030)	(0.096)	.0775698	.0107994	.0228472	(0.022)	(0.054)	(0.060)	(0.012)	-	(0.028)
Sewage treatment (t-2)	0.00813	0.00268	-0.0180	-0.0417	0.00543	0.0497*	-0.0268	-0.0681*	-0.0292	-0.00221	-	-0.00453
	(0.067)	(0.022)	(0.089)	.0943206	.0099066	.0277849	(0.027)	(0.034)	(0.040)	(0.014)	-	(0.018)
Water Losses (t)	0.0349	-0.0150	-0.0987***	-0.0241	0.0210**	-0.0246	0.000465	0.00422	0.0370	0.00406	-	0.0131
	(0.035)	(0.022)	(0.031)	.0156128	.0089025	.0189186	(0.009)	(0.011)	(0.053)	(0.005)		(0.029)
Water Losses (t-1)	0.0550	0.0159	-0.106*	-0.0115	0.00791	-0.0597**	-0.0140	0.00672	-0.0643	-0.00200	-	-0.0532
	(0.042)	(0.031)	(0.054)	.0211225	.0141489	.0267852	(0.013)	(0.015)	(0.062)	(0.007)	-	(0.033)
Water Losses (t-2)	0.0867	-0.0675*	0.0448	-0.0698	0.0160	0.00551	-0.00469	-0.0196	-0.00643	-0.0120	-	0.00442
	(0.153)	(0.035)	(0.186)	.0979671	.0159839	.0555044	(0.044)	(0.055)	(0.072)	(0.018)	-	(0.040)
chlorine (t)	0.111	-0.0419*	0.141	0.109	0.00530	-0.00187	-0.0127	-0.0158	0.000787	-0.0267*	-	-0.00184
	(0.080)	(0.023)	(0.177)	.0895829	.0125404	.0242705	(0.028)	(0.040)	(0.020)	(0.015)	-	(0.017)
chlorine (t-1)	-0.0548	-0.0270	0.0706	-0.0590	-0.0258	0.0120	-0.0562*	-0.00108	-0.0196	-0.0340**	-	0.0187
	(0.108)	(0.030)	(0.183)	.099502	.0162576	.0305117	(0.033)	(0.040)	(0.039)	(0.017)	-	(0.026)
chlorine (t-2)	-0.260**	0.0897**	0.145	-0.100	0.0205	0.00799	-0.0522	0.113*	-0.0123	-0.0345	-	0.0155
	(0.126)	(0.035)	(0.168)	.0651139	.0179343	.0503272	(0.047)	(0.062)	(0.038)	(0.022)	-	(0.027)
turbidity (t)	-0.111	0.0165	-0.111	-0.0871*	-0.0330**	-0.0871*	-0.0374	-0.118	-0.0374	-0.0634*	-	0.00749
	(0.133)	(0.033)	(0.133)	.0449643	.0160624	.0449643	(0.046)	(0.082)	(0.046)	(0.034)	-	(0.032)
turbidity (t-1)	-0.328**	0.0175	0.473**	0.195	-0.0167	-0.00384	-0.0304	-0.229***	0.0409	-0.0495	-	0.00240
	(0.152)	(0.030)	(0.199)	.3535949	.0141558	.0451345	(0.031)	(0.077)	(0.035)	(0.030)	-	(0.027)
turbidity (t-2)	0.231*	0.0704*	-0.409	0.266**	0.0221	0.0112	0.0480	0.139**	-0.0334	-0.0125	-	0.00660
	(0.117)	(0.038)	(0.247)	.1270911	.0175242	.0464316	(0.058)	(0.068)	(0.056)	(0.032)	-	(0.031)
Total Coliforms (t)	0.0738**	-0.0448	1.643	0.00684	0.0162	0.319	0.0598***	0.0643	0.532	0.0391***	-	0.151
	(0.053)	(0.098)	(1.021)	.0205024	.0250181	.3087937	(0.038)	(0.043)	(0.492)	(0.016)	-	(0.207)
Total Coliforms (t-1)	0.149	-0.0635	0.727	0.178	-0.0142	0.481**	-0.215	-0.0358	0.195	-0.0407	-	0.0649
	(0.654)	(0.094)	(0.659)	.3719182	.0415441	.2294145	(0.211)	(0.145)	(0.245)	(0.119)	-	(0.134)
Total Coliforms (t-2)	0.146	-0.118	0.197	-0.187	-0.0507	0.0957	-0.624***	-0.111	0.0550	0.139	-	-0.0618
	(0.735)	(0.094)	(0.476)	.3723006	.0536172	.1830119	(0.180)	(0.174)	(0.128)	(0.093)	-	(0.071)

*** p<0.01, ** p<0.05, * p<0.1

Table A3b: Epidemiological Transition – Hospitalizations per Age

Bias Corrected Model - Morbidity Indicators - fixed rank

	morb1			morb1a4			morb5a9		
	1st quartile	median quartile	4th quartile	1st quartile	median quartile	4th quartile	1st quartile	median quartile	4th quartile
Water access (t)	-0.0260	-0.0700	0.0555	-0.0375	-0.0231	0.185	-9.59e-05*	-0.0754	0.0369
	(0.087)	(0.090)	(0.051)	(0.081)	(0.094)	(0.149)	(0.062)	(0.054)	(0.113)
Water access (t-1)	-0.0151	-0.125	-0.0231	0.0482	-0.134	-0.326*	0.0317	-0.0406	0.0989
	(0.073)	(0.088)	(0.076)	(0.075)	(0.152)	(0.190)	(0.047)	(0.063)	(0.158)
Water access (t-2)	0.117	0.0696	-0.0192	-0.0463	-0.102	-0.273	0.0736	-0.117	-0.412***
	(0.097)	(0.072)	(0.099)	(0.076)	(0.118)	(0.228)	(0.079)	(0.074)	(0.153)
Sewage (t)	-0.113	-0.0124	0.112	0.0414	-0.0457	0.123	-0.0633	-0.0140	-0.0927
	(0.072)	(0.046)	(0.120)	(0.049)	(0.103)	(0.267)	(0.050)	(0.065)	(0.150)
Sewage (t-1)	-0.0151	-0.0371	0.0326	0.0482	0.00181	-0.119	0.0317	0.0686	0.111
	(0.073)	(0.037)	(0.126)	(0.075)	(0.099)	(0.218)	(0.047)	(0.047)	(0.167)
Sewage (t-2)	-0.0262	0.0258	0.0152	0.0531	-0.194**	-0.0426	-0.0441	-0.0935*	0.00342
	(0.078)	(0.034)	(0.043)	(0.057)	(0.092)	(0.064)	(0.053)	(0.051)	(0.050)
Sewage treatment (t)	-0.0681	0.0534	0.0900	-0.111***	0.112	0.102	-0.0309	0.0596	-0.0425
	(0.044)	(0.053)	(0.125)	(0.035)	(0.073)	(0.235)	(0.029)	(0.041)	(0.120)
Sewage treatment (t-1)	-0.0495	0.00236	0.0453	-0.120**	-0.0653	0.293*	-0.0549	-0.0374	0.0504
	(0.042)	(0.034)	(0.125)	(0.052)	(0.089)	(0.147)	(0.043)	(0.046)	(0.126)
Sewage treatment (t-2)	-0.111**	-0.00300	0.192***	-0.0401	0.0941	0.103	0.0399	-0.0437	0.0435
	(0.050)	(0.040)	(0.057)	(0.041)	(0.098)	(0.100)	(0.046)	(0.043)	(0.096)
Water Losses (t)	0.0158	0.0683*	-0.0180	0.0623**	0.0700	-0.0546	0.0104	0.154	0.00476
	(0.028)	(0.040)	(0.063)	(0.025)	(0.107)	(0.080)	(0.031)	(0.121)	(0.032)
Water Losses (t-1)	0.0200	0.0599	-0.0458	0.0692**	0.0349	-0.0538	0.00782	0.102	0.0120
	(0.040)	(0.041)	(0.064)	(0.029)	(0.103)	(0.118)	(0.041)	(0.102)	(0.046)
Water Losses (t-2)	0.00883	-0.0476	-0.0840	0.116*	-0.0596	0.107	-0.00802	-0.00135	-0.0788
	(0.099)	(0.057)	(0.089)	(0.068)	(0.137)	(0.163)	(0.062)	(0.090)	(0.136)
chlorine (t)	0.0338	0.00376	0.0692	0.0425	0.0528	0.0230	-0.0471	-0.140***	-0.119
	(0.058)	(0.070)	(0.050)	(0.049)	(0.079)	(0.080)	(0.045)	(0.052)	(0.082)
chlorine (t-1)	0.170**	-0.108	0.0926	-0.0236	-0.0844	0.285**	-0.0567	-0.161**	-0.144
	(0.077)	(0.091)	(0.055)	(0.060)	(0.091)	(0.133)	(0.048)	(0.072)	(0.101)
chlorine (t-2)	0.0218	-0.197***	0.0694	0.0128	-0.0354	0.376**	-0.119	-0.152*	-0.134
	(0.075)	(0.059)	(0.060)	(0.059)	(0.116)	(0.150)	(0.074)	(0.085)	(0.112)
turbidity (t)	0.0794	-0.00186	0.0794	0.492*	-0.240*	0.492*	-0.0758	-0.240**	-0.0758
	(0.117)	(0.041)	(0.117)	(0.255)	(0.128)	(0.255)	(0.103)	(0.112)	(0.103)
turbidity (t-1)	-0.0924*	0.0136	0.0895	-0.0247	0.0814	-0.0398	-0.0826**	-0.106	0.0373
	(0.048)	(0.042)	(0.124)	(0.051)	(0.081)	(0.321)	(0.037)	(0.088)	(0.112)
turbidity (t-2)	-0.166***	0.00613	-0.0699	-0.215***	-0.247**	-0.125	-0.110***	-0.345***	-0.115
	(0.055)	(0.035)	(0.172)	(0.069)	(0.122)	(0.209)	(0.040)	(0.090)	(0.179)
Total Coliforms (t)	-0.241	0.143	0.0991**	0.250	0.158	0.0313	0.0933	0.0461	0.0711**
	(0.281)	(0.220)	(0.042)	(0.241)	(0.247)	(0.070)	(0.141)	(0.172)	(0.034)
Total Coliforms (t-1)	0.0922	0.334	-0.0340	0.0895	-0.230	0.372	0.225	-0.0129	0.0221
	(0.191)	(0.292)	(0.183)	(0.281)	(0.247)	(0.620)	(0.149)	(0.217)	(0.598)
Total Coliforms (t-2)	-0.0166	-0.0951	-0.357	0.0105	0.450	-0.564	0.0328	0.340	-0.252
	(0.224)	(0.269)	(0.243)	(0.183)	(0.265)	(0.768)	(0.207)	(0.257)	(0.654)

*** p<0.01, ** p<0.05, * p<0.1

Table A3c: Epidemiological Transition – Hospitalizations per Disease

Bias Corrected Model - Morbidity Indicators - fixed rank

	diarrhea			dysentery			hepatitis			acute respiratory infection		
	1st quartile	median quartile	4th quartile	1st quartile	median quartile	4th quartile	1st quartile	median quartile	4th quartile	1st quartile	median quartile	4th quartile
Water access (t)	-5.92e-08	-0.0176***	0.0534	-7.39e-07	-0.0176*	-0.0555*	1.71e-07	-0.000201	-0.00215	5.57e-05***	-0.0722***	-0.00829
	(0.006)	(0.006)	(0.052)	(0.008)	(0.010)	(0.029)	(0.001)	(0.000)	(0.001)	(0.036)	(0.020)	(0.040)
Water access (t-1)	0.00356	-0.00638	0.0122	-0.00430	-0.00420	0.0242	-0.000156	-0.000186	-0.00183**	-0.000812	-0.0353**	-0.0797
	(0.005)	(0.007)	(0.024)	(0.004)	(0.010)	(0.022)	(0.001)	(0.000)	(0.001)	(0.009)	(0.017)	(0.050)
Water access (t-2)	0.00962*	-0.00514	0.00682	0.00114	-0.00459	-0.0462***	-0.000589	-0.000177	-0.000606	-0.0455**	0.0148	-0.0683
	(0.005)	(0.006)	(0.029)	(0.006)	(0.008)	(0.017)	(0.001)	(0.001)	(0.001)	(0.021)	(0.020)	(0.057)
Sewage (t)	0.000442	-0.000571	0.0407	-0.00546	-0.0104	0.00521	-0.000815	0.000217	0.000141	-0.0197	-0.0164	0.101*
	(0.009)	(0.005)	(0.038)	(0.004)	(0.006)	(0.032)	(0.001)	(0.000)	(0.000)	(0.016)	(0.018)	(0.056)
Sewage (t-1)	0.00356	-0.000993	0.0484	-0.00430	-0.00341	-0.00692	-0.000156	0.000200	0.000385	-0.000812	0.00763	0.0616
	(0.005)	(0.004)	(0.030)	(0.004)	(0.007)	(0.024)	(0.001)	(0.000)	(0.000)	(0.009)	(0.013)	(0.071)
Sewage (t-2)	0.00311	0.00541	0.0114	-0.00418	-0.00385	0.0108**	6.72e-05	).000323**	0.000217	-0.00875	-0.00132	-9.71e-05
	(0.003)	(0.003)	(0.018)	(0.004)	(0.004)	(0.005)	(0.001)	(0.000)	(0.000)	(0.010)	(0.011)	(0.075)
Sewage treatment (t)	0.00101	0.00688	-0.0171	0.00305	-0.00501	-0.0542***	-0.000239	-0.000217	0.000157	0.00221	0.00347	-0.0133
	(0.003)	(0.005)	(0.022)	(0.003)	(0.005)	(0.020)	(0.001)	(0.000)	(0.000)	(0.013)	(0.010)	(0.043)
Sewage treatment (t-1)	0.00115	-0.00179	0.00523	-0.00150	-0.00239	0.0248**	-0.000364	-0.000371	6.18e-05	0.00863	0.00100	0.0701**
	(0.003)	(0.006)	(0.010)	(0.003)	(0.006)	(0.012)	(0.001)	(0.000)	(0.000)	(0.009)	(0.011)	(0.030)
Sewage treatment (t-2)	-0.00455	-0.000866	-0.00662	0.000382	-0.00709	0.00745	-0.000694	9.86e-05	0.000647*	0.00461	-0.00662	0.0342
	(0.003)	(0.004)	(0.009)	(0.003)	(0.005)	(0.013)	(0.001)	(0.000)	(0.000)	(0.009)	(0.014)	(0.033)
Water Losses (t)	0.00352	0.00612**	-0.00362	0.00279	0.00340	0.00341	0.000678	-6.29e-05	8.83e-05	0.0110	0.00980	-0.00305
	(0.002)	(0.003)	(0.006)	(0.003)	(0.006)	(0.006)	(0.000)	(0.000)	(0.001)	(0.008)	(0.017)	(0.007)
Water Losses (t-1)	0.00618**	0.00641	-0.0131*	0.00154	0.00745	-0.0121	0.00112**	0.000838*	4.69e-05	0.00315	0.00916	0.00471
	(0.003)	(0.004)	(0.007)	(0.004)	(0.006)	(0.009)	(0.001)	(0.000)	(0.001)	(0.011)	(0.016)	(0.011)
Water Losses (t-2)	0.00119	0.00250	0.00842	-0.00297	0.0140	-0.0218	5.82e-05	-0.00122**	-0.000775	0.0126	-0.0425*	-0.0697
	(0.004)	(0.006)	(0.014)	(0.005)	(0.012)	(0.014)	(0.001)	(0.001)	(0.001)	(0.017)	(0.023)	(0.045)
chlorine (t)	-0.00257	0.00443	0.00187	-0.00640	0.00813*	0.00430	0.00114	0.000168	-0.000136	0.0475**	-0.0131	0.00873
	(0.003)	(0.003)	(0.016)	(0.005)	(0.004)	(0.011)	(0.001)	(0.000)	(0.000)	(0.022)	(0.011)	(0.018)
chlorine (t-1)	-0.00423	-0.000354	-0.0201	0.00622	0.00725	-0.0152	0.000162	1.20e-05	-0.000333	0.0371	-0.0178	5.52e-05
	(0.004)	(0.006)	(0.018)	(0.011)	(0.007)	(0.013)	(0.001)	(0.000)	(0.001)	(0.031)	(0.014)	(0.024)
chlorine (t-2)	-0.0211	-0.000333	-0.0222	0.0426**	-0.0172**	0.0409	0.000898	).000761**	-0.000984	0.00672	-0.0283	0.0635**
	(0.032)	(0.012)	(0.016)	(0.018)	(0.008)	(0.027)	(0.001)	(0.000)	(0.001)	(0.028)	(0.020)	(0.031)
turbidity (t)	-0.0264	-0.00355	-0.0264	-0.00546	-0.00167	-0.00546	-0.000309	0.000385	-0.000309	-0.103	0.0133	-0.103
	(0.020)	(0.006)	(0.020)	(0.018)	(0.004)	(0.018)	(0.000)	(0.000)	(0.000)	(0.066)	(0.014)	(0.066)
turbidity (t-1)	0.00895	-0.00184	-0.00585	-0.00266	-3.25e-05	-0.0163	0.00211**	-0.000235	-0.000551	0.0262	-0.00915	-0.100
	(0.008)	(0.005)	(0.024)	(0.011)	(0.006)	(0.014)	(0.001)	(0.000)	(0.000)	(0.018)	(0.014)	(0.096)
turbidity (t-2)	-0.00326	9.44e-05	-0.00383	0.00731	-0.00402	-0.0100	-0.00173*	-0.000730	-0.000249	0.0304	0.00108	-0.132**
	(0.004)	(0.007)	(0.019)	(0.006)	(0.005)	(0.016)	(0.001)	(0.001)	(0.000)	(0.022)	(0.014)	(0.063)
Total Coliforms (t)	-0.00115	-0.0116	0.111	0.00796	-0.0266	0.00456	0.000512	5.37e-05	0.00146***	-0.0230	-0.0629	0.0220
	(0.004)	(0.017)	(0.067)	(0.020)	(0.025)	(0.006)	(0.006)	(0.000)	(0.000)	(0.053)	(0.044)	(0.019)
Total Coliforms (t-1)	-0.0289	0.00104	0.0166	-0.0233	-0.0131	0.129	-0.0111**	-0.00112	0.000427	-0.0947*	-0.0763	-0.0201
	(0.040)	(0.023)	(0.041)	(0.023)	(0.031)	(0.077)	(0.005)	(0.001)	(0.002)	(0.051)	(0.054)	(0.138)
Total Coliforms (t-2)	0.0220	-0.0308	0.0114	-0.0496*	0.0203	0.00908	-0.00907**	-0.00251**	0.00693***	-0.0179	0.0226	-0.0188
	(0.031)	(0.025)	(0.033)	(0.027)	(0.032)	(0.070)	(0.003)	(0.001)	(0.003)	(0.052)	(0.058)	(0.145)

*** p<0.01, ** p<0.05, * p<0.1