Empirical evidence of the effect of sanitation policies on health indicators for Brazilian municipalities

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ABSTRACT

This paper investigates the effects of sanitation policies on health indicators in a panel of Brazilian municipalities. Specifically, we use DataSUS, the IBGE, and the SNIS to assess whether the indicators of sanitation affect the health indicators of mortality and morbidity by age group and by different diseases in the municipalities from 2001 to 2008. We work with different samples due to an unbalanced panel because there are missing data on sanitation in smaller municipalities and for lower income people. The results show that we cannot ignore the importance of sanitation. Our results indicate that for the entire sample, a 1% reduction in the incidence of total coliform implies a decline of 0.12 deaths for children under one year of age, including the neonatal period, for every thousand live births. Regarding hospitalization due to illness, only improvement in access to water and a reduction in total coliforms seem to reduce hospitalization for dysentery (for access to water) and hepatitis and tuberculosis (for total coliforms). Access to sewage services seems to reduce the mortality of children up to four years of age and hospitalizations of children aged five to nine years in poor municipalities. Finally, access to water and sewers appears to reduce hospitalizations due to dysentery and hepatitis in municipalities with an income above the median in Brazil.

JEL: C23, C5, I1.

1. Introduction

The issue of basic sanitation is increasingly on the public policy agenda in Brazil. The country is a signatory of the Millennium Development Goals of the United Nations, which includes a commitment to sanitation goals. The topic is under scrutiny in the printed media,[1] which demand rapid and efficient investments and criticize the current situation in the sector. There is a tendency in Brazil to universalize access to piped and drinking water, but the nationwide access network for the collection and treatment of sewage remains relatively underdeveloped. This situation calls for studies on the subject.

Using panel data from Brazilian municipalities, the present article proposes to analyze the effect of variables related to basic sanitation on health indicators. We argue that advances in the sanitation sector can have a positive impact on the wellbeing of citizens and can generate externalities. Investments in sanitation in Brazil have not reached 0.5% of GDP in the last 15 years (Neri, 2007). Furthermore, concern about the quality of sanitation services has grown. Improvement in water quality, reduction of waste, the condition of sewerage, and other factors beyond the issue of access to water can therefore provide better living conditions. According to Seroa da Motta (2004), basic sanitation is clearly important to the health and welfare of citizens and has a positive effect on the environment; that is, public investment in sanitation produces positive impacts for other sectors of the economy, particularly agriculture, education, labor, and tourism, which in turn can increase the efficiency of public policies.

A new database linking annual sanitation and health information in Brazilian municipalities allows us to perform an econometric evaluation that is not merely quantitative, such as measuring access to drinking water, but also allows qualitative evaluations, such as identifying the channels that impact citizens' health. Therefore, the present study uses panel data from Brazilian cities with a sample based on the decade of the 2000s. We sought to identify the effect of improved quality and access to water on health indicators, such as diarrhea, dysentery, cholera, and polio. Thus, the present study is the first to distinguish variables that measure the effect of both the quantity (coverage or access) and the quality (the fecal coliforms rate or sewage treatment, for example) of the sanitation service on health indicators, including deaths and hospitalizations.

The present article aims to contribute to the literature in different ways. The

[1] According to editorials in O Estado de São Paulo (2011) and Folha de Sao Paulo (2010).

study’s first contribution is to use a newly available sanitation database containing municipalities' annual information. The second and perhaps main contribution is to distinguish the importance of items related to the quantity and quality of water from the reduction of diseases and deaths related to a lack of sanitation. As infant mortality continues to decline, the present study also emphasizes the issue of morbidity, including hospitalization due to disease. The final contribution is to help implement effective public policies in the sector from two standpoints: first, to identify the channels related to basic sanitation that impact health indicators, and second, to assess the results of investment in sanitation, producing a cost-benefit analysis of this and other policies.

The article is organized as follows: the following section summarizes the literature regarding topics covered in the subsequent sections. Section 3 aims to introduce the data used, form the descriptive analysis, and begin the discussion about the unbalanced nature of the panel database. Section 4 contains the empirical implementation, the presentation of results, and the cost-benefit analysis. Finally, section 5 offers our conclusions.

2. Literature Review

2.1. Sanitation

Growing concern about the universalization of basic sanitation services in recent decades has led to the emergence of studies on the impact of changes in access to water and sewerage services on the population’s health. These studies are driven by the existence of diseases due to sanitation imperfections. Galdo and Briceño (2005) note that diseases borne directly or indirectly by water comprise four different types. First, many diseases are caused by poor water quality, such as diarrhea, dysentery, cholera, and polio. Other diseases are related to lack of sanitation when the volume of water is insufficient for personal hygiene. There are also diseases caused by organisms that live in water, such as schistosomiasis and roundworm, and diseases transmitted by insects from polluted aquatic environments, such as malaria, dengue fever, and yellow fever. Thus, factors beyond the supply of water itself cause the emergence of these diseases, which can result in worsening health indicators.

A pioneer of econometric studies, Merrick (1983) sought to measure the effects of sanitation on the health of the Brazilian population, using data from the 1970 Census

and the National Survey of Sample Households (Pesquisa Nacional de Amostra dos Domicílios - PNAD) of 1976. Increased access to piped water in these six years was assessed to verify whether it helped in any significant way to reduce infant mortality in the urban population. For this assessment, a simultaneous equations model was used in which infant mortality rate, binary variables of access to water, and income of the parents were considered to be endogenous components, as the study was interested both in what led to the consumption of water and the implications of this consumption. This analysis showed that despite maternal education having a greater effect because it affected family income, access to piped water was also significant for the improvement of health indicators.

The influence of education on the health of citizens raises the possibility of the significance of the interaction between education and sanitation. With data from the Philippines, Barrera (1990) showed that maternal education and access to a water connection are substitutes for the health of children up to 15 years; that is, the interaction between these variables has a negative correlation, as mothers with more schooling are better able to care for their children even without access to water and sewerage. Thus, sanitary infrastructure and maternal education are complementary benefits with positive interaction between the variables possibly because families with more education better appreciate the value of heath care. Even in Brazil, Kassouf (1995) found negative correlations in the interactions between maternal education and sanitation for all age groups, using height in relation to children's ages as the dependent variable.

Using a municipal database and the economic value of reducing mortality as a dependent variable through an intertemporal model, Soares (2007) added illiteracy as a control variable to assess the influence on life expectancy of Brazilians between 1970 and 2000. The author estimated that access to water and education have economic value that is three times greater than sewage treatment, although all of these variables were significant. Using Census data from 1970 to 2000, Alves and Beluzzo (2004) concluded that education, basic sanitation, income per capita, and economic growth help to reduce the country's mortality rate. These studies use both panel estimations for fixed effects and dynamic panels as proposed by Arellano and Bond (1991) to address the alleged endogeneity problem because the progress of sanitation predominates in areas with poor quality of life and health, which generates reverse causality.

Brazil’s strong regional disparities imply a greater likelihood that the condition of

sanitation also differs from area to area. Given this condition, Gamber-Rabindran, Khan, and Timmins (2007) analyzed the impact of piped water on the infant mortality rate in Brazil through quantile regressions and evaluated the interaction with access to other basic infrastructures. The result was that access to piped water had little effect in areas with worse development, and the effect increased according to the region's development to reach an optimal level before beginning to decline. Nevertheless, the effect was significant. However, Sastry and Burgard (2005) suggest that the mere expansion of sanitation and water supply is not sufficient to reduce cases of diarrhea in the northeast region.

Other studies have assessed the effect of sanitation on health indicators in other developing countries in recent decades. Using data from India, Java and Vallaion (2003) concluded that increased access to water supply only impacted the reduction of diseases such as diarrhea in children if it was accompanied by other public policies. In Latin America, Galdo and Briceño (2005) found evidence of the impact of sanitation on the health of Ecuadorian children, and Checkley et al. (2004) noted that the height of children in Peru was impacted by sanitation. Lee, Rosenzweig, and Pitt (1997) observed the impact of sanitation on child mortality in Bangladesh and the Philippines, using a semiparametric estimation and maximum likelihood because the proposed model, which included nutritional aspects, caused biased estimates using the method of least squares and because of the assumption that mortality does not have a known distribution. Lee, Rosenzweig, and Pitt (1997) found that neither variation in the type of water supply nor sanitation improvements had a significant effect and that only wealth and parental education contributed significantly to children's survival rates. Regarding diseases, Esrey et al. (1991) compiled several studies evaluating the impact of access to water and sewerage systems on diseases. The authors concluded that improvements in sanitation promote effective reduction of morbidity from ascariasis, diarrhea, guinea worm, schistosomiasis, and trachoma. Additionally, sanitation reduced the severity and fatality of these diseases, highlighting the positive externalities generated.

Watson (2006) assessed the impact of the expansion of sanitation in indigenous U.S. communities during the second half of the twentieth century. This expansion resulted from investments generated by the Sanitation Facilities Construction Act (SFC), which authorized sanitation improvements on indigenous reservations with a budget approved annually by Congress. In the study, the calculation was performed using panel data for a sample of 38 U.S. counties with the highest indigenous populations between 1960 and

1998. The results showed that indigenous infant mortality would have been 51% higher if there were no such sanitation program, and this result explains 40% of the decrease in the difference in infant mortality between indigenous Americans and whites since 1970. This impact occurred primarily at the post-neonatal age (between one and 12 months) of indigenous children; the effect on neonatal mortality (within one month of life) was not found to be significant. The study also showed reductions in gastrointestinal and respiratory diseases in indigenous Americans due to the SFC. Moreover, there is evidence of health externalities in areas with a predominantly white population that is close to indigenous American reservations, both directly (through access to water) and indirectly (by reducing respiratory diseases).

There are also studies on public policy experiments in the sanitation sector. Devoto et al. (2011) assessed the impact of sanitation in the urban area of Tangier, one of the largest cities in Morocco, where water was only supplied to public places close to homes, creating time costs with the collection of drinking water. The experiment, conducted in 2008, aimed to inform and make available interest-free credit loans of between three and seven years to a random group of families with the goal of establishing direct access to sanitation in their homes, whereas the control group could have access to credit but had little or no information about it and faced greater bureaucracy to obtain it. These conditions caused the treatment group to have greater access (69%) than the control group (10%) to the direct connection of piped water. The experiment led to an increased amount of water consumed by households but did not alter its quality (measured by the incidence of bacteria in the water, which, according to the abovementioned article, is correlated with the rate of fecal coliform), although the water's chlorine content was increased. The impact of this increase on water-related diseases was then evaluated. Randomization allowed that estimation by ordinary least squares was non-biased. The impact of treatment on the occurrence of diarrhea in children aged zero to five years and on infection of the skin and eyes in children and adults was negligible. However, the intervention of sanitation was noted to increase the families' quality of life. With the convenience of running water at home and without cost to obtain it, there was an increase in leisure activities, such as television, bath time, and visits of family and friends.

Another study involving experiments and the impact of sanitation on disease is that of Kremer et al. (2010), who studied the effect of sanitation in Kenya, where water is considered to be a common resource without the establishment of property rights; thus,

there are individual searches for sources of drinking water, which can lead to the tragedy of the commons. In Kenya, 43% of people drink water from sources that are mostly in private areas. The experiment involved randomly selecting 200 sources of water to receive protection in different phases. This protection inhibited the emergence of new sources, reducing the risk of water contamination. The protected water sources in the first two stages of the process were the treatment group, and the other sources were the control group. Through linear regression, evidence of the impact of the protection indicator of water sources on the decrease of the bactericidal index of the source water could be observed. Kremer et al. (2010) found that water quality improved in individuals' homes, beyond the impact of the protection indicator on the cases of diarrhea in children under three years of age.

2.2. History of Sanitation in Brazil

Compared with other developed countries, Brazil's sanitation services have expanded relatively recently. For example, as noted by Cutler and Miller (2005), access to piped water services in the U.S. increased between the last decade of the nineteenth century and the first two decades of the twentieth century. In less developed countries, progress in basic sanitation has increased over the past century, whereas in Brazil, progress in this sector only emerged in the second half of the twentieth century. Nevertheless, the provision of sanitation to the Brazilian population has experienced significant growth in recent decades. Oliveira (2008) and Turolla (2002) note that this change occurred with the seizure of power by the military governments in the 1960s, through the creation of the National Housing Bank (Banco Nacional de Habitação - BNH). The BNH, by means of the Financial System of Sanitation (Sistema Financeiro do Saneamento- SFS), provided the Employee’s Severance Guarantee Fund (Fundo de Garantia do Tempo de Serviço – FGTS) collection, which financed expansion of the sector. In the 1970s, the National Sanitation Plan (Plano Nacional de Saneamento - Planasa) was created, which focused on investments in sanitation. Planasa gave the newly created State Basic Sanitation Companies (Compania Estaduais de Saneamento Básico - CESBs) exploration rights in water and sewerage services, creating economies of scale and funding them through the BNH. Thus, there was a large-scale expansion of the piped water network during the 1970s. In the following decade, the economic crisis, hyperinflation, and the extinction of the BNH caused a marked decrease in Planasa's

investments in the sector's companies, curbing the expansion of sanitation.

The basic sanitation policy of the 1990s was notable for a series of specific federal programs to reduce inequality in access to sanitation, to modernize the system, and to ensure economic viability for water and sewerage services throughout the country. There was a change in the regulatory framework through decentralization provided in the 1988 Constitution and a series of measures,[2] such as the Program for the Modernization of the Sanitation Sector (Programa de Modernização do Setor de Saneamento - PMSS), which began in 1995 to provide technical assistance in the provision of sanitation to the union, the states, and the municipalities. The Concessions Law 8,987 (Lei de Concessões 8.987) (1996) allowed the private sector to participate in the sanitation field, and the Law project n° 4,147/2001 created the National Water Agency (Agência Nacional de Água - ANA). In 2007, the General Law of Basic Sanitation (Lei Geral do Saneamento Básico) was approved and set new national guidelines for the sector and for federal policy on basic sanitation (BRAZIL, 2007). With regard to the future, Brazil is a signatory of the Millennium Development Goals of the United Nations, which committed to eight goals, including a two-thirds reduction in infant mortality from 1990 to 2015 and a 50% decrease in lack of access to drinking water by 2015. However, these goals can be met only if the speed of improvement in the level of sewerage is doubled.[3]

The result of these actions was the improvement of access to water and sewerage. According to Censuses data between 1970 to 2000, the coverage of piped water services increased from 32.8% to 76.6% of households, and the percentage of households connected to the general sewerage network increased from 13.1% to 46.5%. Mendonça and Motta (2005) and Saiani (2007) showed that coverage levels of treated water and sewerage for the population also increased in the last four decades. Increased access to sanitation has also occurred in the pediatric population: Neri (2007) showed that according to National Survey of Household Sampling (Pesquisa Nacional por Amostra de Domicílios - PNAD) data, the access of children aged zero to four years to sewerage increased from 29.14% in 1992 to 40.37% in 2006. Such access increases with the age of the individual.

With regard to the improvement in services, it is worth noting the heterogeneity

[2] Saiani and Toledo (2005) and Neri (2009) detailed the other laws on sanitation implemented in the period.
[3] This information was reported in the media (O Estado de São Paulo, 2011).

of the sanitation expansion in Brazil. Figures 1A and 1B show the regional distribution of access to water supply and sewerage systems, respectively, according to 2000 Census data. The figures below show the proportion of inhabitants of each microregion with access to the general water supply (piped into the property or at least into one room) and access to general sewerage. Note that regional dispersion is similar: the microregions of the center-south of the country have more advanced levels of sanitation than the Amazon and northeast microregions. In most of the country, access to water is higher than to the sewerage system.

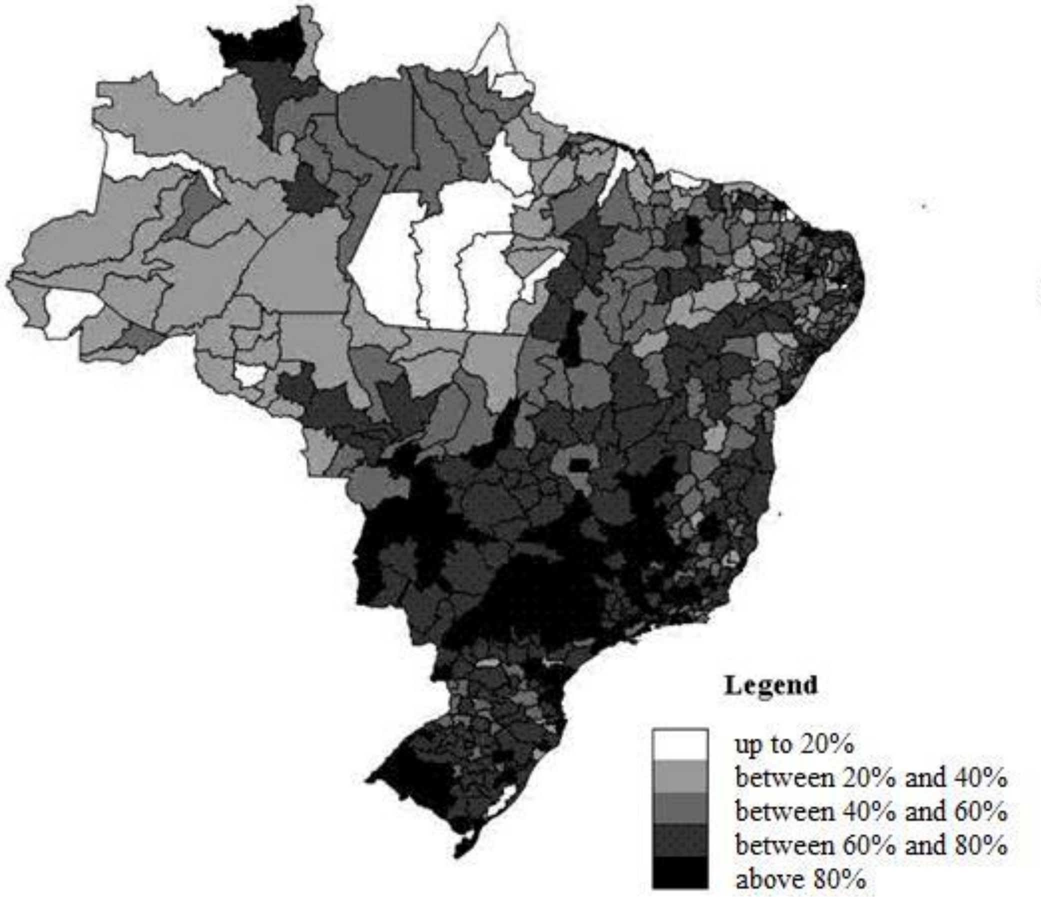
2.3. Sanitation and Health

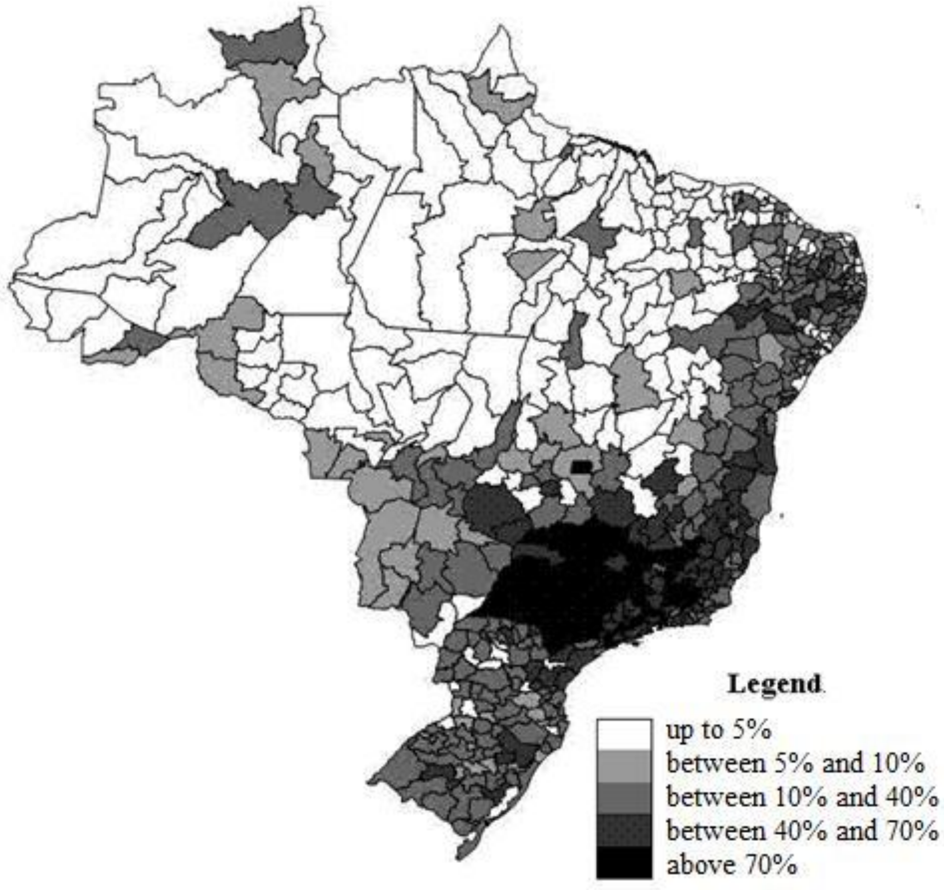
The reduction in the infant mortality rate is significant over time. In the 1970 Census, the ratio was 123.2 people who did not complete one year of life per thousand live births. This ratio declined to 83.2, 44.7, and 30.6 deaths per live births in the 1980, 1991, and 2000 Censuses, respectively. In the last decade, there was also a clear improvement in infant mortality rates, although the decline is decreasing compared with previous decades. Figures 2A and 2B show the distribution of infant mortality rates calculated from the ratio of infant deaths (up to one year) to the number of live births for the Brazilian microregions in 1999 and 2008, respectively. In 1999, there were few microregions with an infant mortality rate below 15 deaths per thousand live births, but in 2008, the number of such regions increased in the center-south of the country.[4]

With respect to world data, there was also improvement in health indices. The number of deaths in children under five years of age declined from 12.5 million in 1990 to less than 9 million in 2008 (UNICEF, 2009), reducing mortality in the zero-to-one-year age group from 90 to 65 deaths per thousand live births. Approximately 15% of child deaths worldwide are still related to diarrhea (UNICEF, 2001). In addition, polio in children is approaching worldwide eradication.

[4] Details on the regional dimension of infant mortality can be found in Barufi (2009).

Figures 1A and 1B - Access to general piped water and sewerage networks, respectively, in Brazilian microregions in 2000





Source: Prepared by the IPEAGeo program from 2000 Census data.

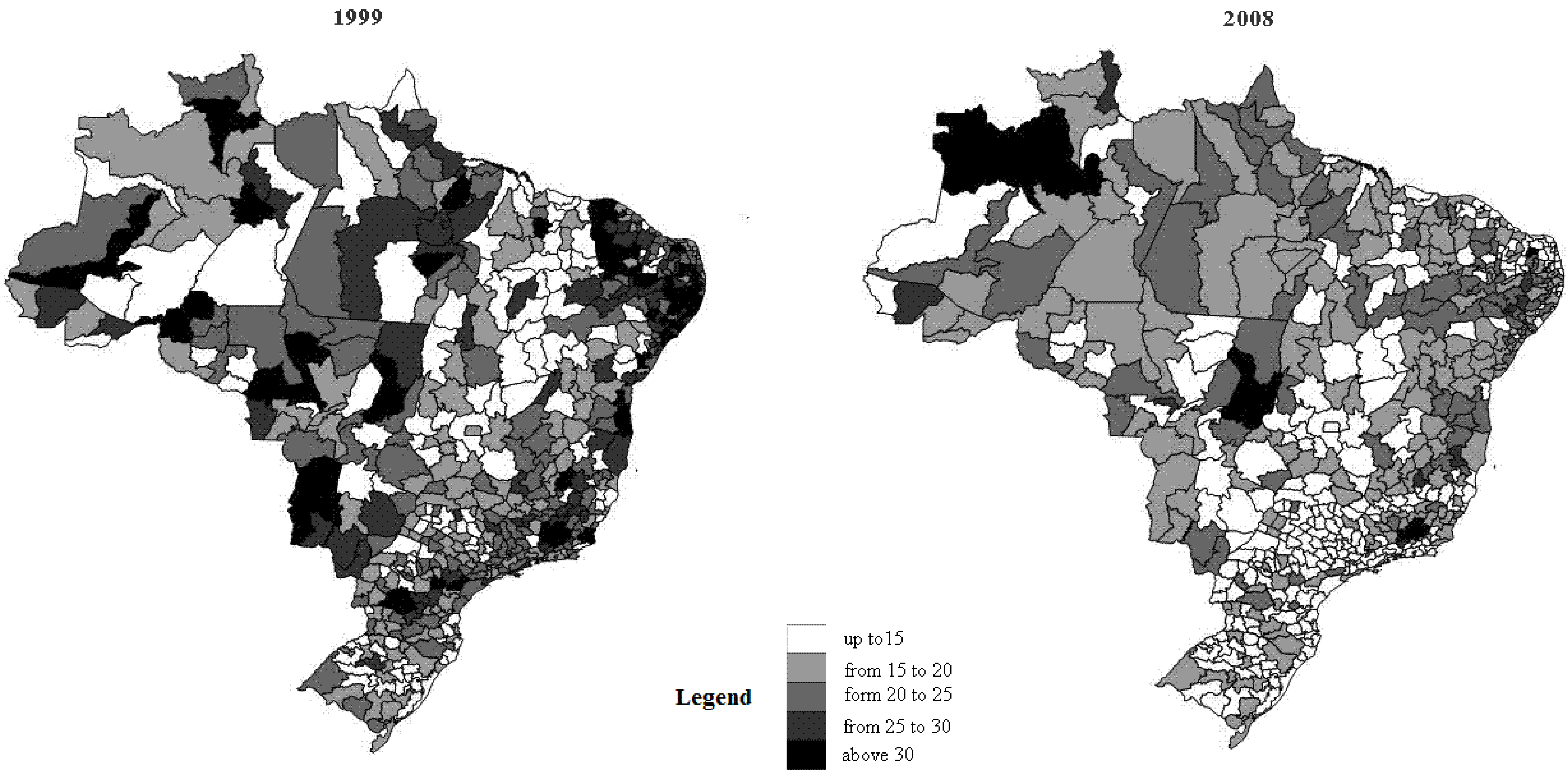
Among other causes of reduction in infant mortality in recent decades, the impact of the Family Health Program (Programa de Saúde da Família - PSF) on infant health was assessed by Serra (2003). The PSF, launched in 1994, provided medical teams and health care agents to bridge the gap between neglected families and health services, working towards primary care and disease prevention. Serra found that the adoption of the PSF helped to reduce the infant mortality rate in São Paulo municipalities with more than 50,000 inhabitants between 1998 and 2001. Rocha (2009) found a reduction in mortality in children, adults, and the elderly in the municipalities that participated in the PSF, and the author demonstrated positive externalities for such policies, which affect school attendance and the labor market.

There are two issues in the econometric use of information on health indicators such as morbidity and mortality: underreporting and reliability of the underlying cause of death or hospitalization. Underreporting may occur, especially in infant mortality, but this rate is expected to have declined in recent years. The proportion of ill-defined causes can be used as a proxy to assess reliability levels. According to the methodology[5] of Berenstein and Lacerda (2002), it can be observed that poor definition of causes has decreased each year both for infant mortality and for general mortality and morbidity. National data are shown in Table 1, representing a decrease of more than 50% in ill-defined causes of death in a decade and the maintenance of morbidity levels. This decrease implies that cases of death due to sanitation-related diseases are slightly underestimated in the early years of the sample. In the case of hospitalizations, ill-defined causes do not exceed 2% of the sample and can therefore be considered negligible.

With regard to the cost-benefit analyses involving the improvement of sanitation in Brazil, there is evidence that money spent on sanitation is more effective than that spent on healthcare when the goal is to save a life. Considering the period between 1981 and 2001, Mendonça and Seroa da Motta (2005) indicated that investment in sewage treatment coverage and access to water were, respectively, 17% and 67% more effective than investment in healthcare, whereas investment in reducing illiteracy was even more effective in reducing mortality in children between zero and four years old.

[5] The total amount of data found in Section XVIII (symptoms, signs, and abnormal findings of clinical and laboratory exams) of the ICD-10 (International Classification of Diseases, which can be found on the DataSUS site) is considered to be the proportion of ill-defined causes of the total figures provided by the ICD-10.

Figures 2 A and 2B - Rate of deaths in children under one year of age per thousand live births in Brazilian microregions in 1999 and 2008



Source: Prepared by the IPEAGeo program from 2000 Census data.

Table 1- Proportion of ill-defined causes of mortality and morbidity

Year	% ill-defined infant deaths	% ill-defined general deaths	% ill-defined general hospitalizations
1999	11.54%	15.09%	1.16%
2000	12.30%	14.34%	1.23
2001	10.00%	14.12%	1.30%
2002	8.82%	13.65%	1.21%
2003	8.35%	13.31%	1.20%
2004	6.88%	12.39%	1.30%
2005	5.32%	10.37%	1.30%
2006	4.56%	8.29%	1.34%
2007	4.03%	7.66%	1.43%
2008	3.92%	7.35%	1.30%

Source: DATASUS

According to Neri (2007), investment in sanitation can be up to four times more effective than mere investment in healthcare. Such analyses may be underestimated because investment in sanitation can also reduce morbidity, i.e., the expansion of sector indicators can reduce hospitalizations and thus contribute effectively to saving lives.

3. Data and Analysis

3.1. Data

In Brazil, access to running water has always comprised the sanitation sector's main data, which are provided by the decennial IBGE Census and cover the entire country. The data are also provided by the annual PNAD, which covers the self-representing metropolitan municipalities and whose calculation of access to water is based on the proportion of inhabitants and households in the country that have access to piped water and sewage treatment. The issue of water quality provided to the population has never been the main focus of literature studies on this sector mainly because of the absence of such information in the country.

However, there is now a national database that covers information both on

access to and quality of the water service. The SNIS is a database linked to the Federal Government’s Ministry of Cities (Ministério das Cidades do Governo Federal), which gathers information about state, regional, and municipal service providers of access to water and sewage treatment. The SNIS was founded in 1995 through the development of the Sanitation Sector’s Modernization Program (Programa de Modernização do Setor de Saneamento) and contains data for 2008 from 4,610 Brazilian municipalities (of a total of 5,564) with 77 indices, 27 sets of data on access to water, 15 sets of data on sewerage systems, 35 sets of financial data about sanitation contractors in the city, 14 sets of general data, such as how sanitation contracts were awarded to particular companies and the municipality's urban population, and 25 sets of data involving water quality. Of these variables, we selected the samples whose rates are more related to health variables and those with numerous observations. These variables are summarized with their expected impact on mortality and morbidity in Table 2.

Table 2 - Description of sanitation variables

Name	Description of Variable	Expected Sign
in013	Revenue loss rate [percentage]	+
in015	Sewage collection rate [percentage]	-
in016	Sewage treatment rate [percentage]	-
urwater_service	Urban water service rate [percentage]	-
in024	Urban sewage service rate for cities served with water [percentage]	-
in028	Water revenue rate [percentage]	-
in046	Treated sewage rate for water consumed [percentage]	-
in047	Urban sewage service rate for cities served with sewerage [percentage]	-
in049	Distribution loss rate [percentage]	+
in052	Water consumption rate [percentage]	-
losses_inc	Loss rate per connection [l. / Day / conn.]	+
water_service	Total water service rate [percentage]	-
in056	Sewage service rate for cities served with water [percentage]	-
fluoridation	Fluoridated water rate [percentage]	-
nonstandard_chlorine	Incidence of nonstandard residual chlorine analyses	+
turbidity_inc	Incidence of nonstandard turbidity analyses	+
in078	Incidence of nonstandard fecal coliform analysis [percentage]	+
in079	Rate of conformity of sample quantity - chlorine residual [percentage]	+
in080	Rate of conformity of sample quantity - turbidity [percentage]	+

total_coliform_inc	Incidence of total nonstandard fecal coliform analysis [percentage]	+
in085	Rate of conformity of sample quantity - total coliforms [percentage]	+
in101	Cash sufficiency rate [percentage]	-

Source: SNIS

For health indicators, the DataSUS will be used, which contains health information from Brazilian municipalities. Hospitalization data (morbidity) and deaths (mortality) are used as indicators, which will be divided in different ways, generating the information shown in Table 3. Indicators in the data are first separated according to age: in the case of death, this separation provides a rate of infant mortality (up to one year of age), deaths of children between one and 12 months (excluding the neonatal period), from one to four years, and five to nine years. With the same approach, the general rate of hospitalization is divided into up to one year of age, from one to four years of age, and from five to nine years of age. To achieve a measurable rate among municipalities, the relationship between each of these variables and the number of live births in that year was calculated.

Table 3 - Description of Dependent Variables

Name	Type	Description of Variable
dea_1 to12_n	mortality	deaths of one to 12 months per thousand live births
dea5_9_n	mortality	deaths of five to nine years per thousand live births
dea1_4_n	mortality	deaths of one to four years per thousand live births
hop1_4_n	morbidity	hospitalizations of one to four years per thousand live births
hop5_9_n	morbidity	hospitalizations of five to nine years per thousand live births
hop_diar_n	morbidity	hospitalizations due to diarrhea per thousand live births
hop_dys_inh	morbidity	Dysentery hospitalizations per hundred thousand inhabitants
hop_pol_inh	morbidity	Polio hospitalizations per hundred thousand inhabitants
hop_trac_inh	morbidity	Trachoma hospitalizations per hundred thousand inhabitants
hop_hep_inh	morbidity	Hepatitis hospitalizations per one hundred thousand inhabitants
hop_chol_inh	morbidity	Cholera hospitalizations per hundred thousand inhabitants
hop_tb_inh	morbidity	TB hospitalizations per hundred thousand inhabitants
hop_tet_inh	morbidity	tetanus hospitalizations per hundred thousand inhabitants

hop_diph_inh	morbidity	diphtheria hospitalizations per hundred thousand inhabitants
hop_diar_inh	morbidity	Diarrhea hospitalizations per hundred thousand inhabitants

Source: DATASUS

Additionally, the data can be separated according to morbidity by type of disease. As mentioned, there are numerous sanitation-related diseases. According to the methodology of Guido and Briceño (2005), diarrhea, dysentery, cholera, polio, and hepatitis A and E are diseases caused by pollution and water contamination and are therefore related to sanitation quality. Similarly, trachoma, tuberculosis, tetanus, and diphtheria are diseases related to water scarcity when an individual has difficulties accessing sanitation. Thus, morbidity rates for each disease mentioned have been isolated, and the data were retrieved from the ICD-10 morbidity list in DataSUS. The relationship between each of these variables and the number of inhabitants in each city was calculated to compare across different locations.

The following categories were used as control variables: population data, which are estimates made by IBGE on July 1 of each year from 1999 to 2006 and 2008, with the count conducted in 2007 for each municipality; the municipalities' Gross Domestic Product (GDP) also provided by IBGE, measured based on 2000 figures, deflated by the National GDP implicit deflator, and calculated by the distribution of added value to main economic activities (IBGE, 2008). The ratio of enrollment in day care and preschool to the population of children between zero and four years of age as measured by the Schools' Censuses, the vaccination coverage (immunization coverage) in the cities, the percentage of people enrolled in the Family Health Program by municipality, and year dummies were also used. These data with their expected impact on the model are shown in Table 4.

Table 4 - Description of control variables

Name	Description of Variable	Expected Sign
Gdppc	GDP per capita	-
ln_pop	log municipal population	?
school	enrollment in day care and pre-school/child pop	-

Psfpcap	attendance in the Family Health Program	-
vacc_cov	vaccination coverage	-

Source: IBGE, DATASUS

3.2. Descriptive Analysis

The database refers to the years between 1999 and 2008 and comprises 24,858 observations. However, information is not available for every municipality. As noted by Neri (2009), SNIS data are furnished by sanitation service providers in each municipality. Despite regulation of the information provided, data on water supply and sanitation were provided voluntarily until 2008.[6] Thus, sanitation companies that served poorer cities or had worse sanitation rates had little incentive to submit complete information to the Ministry of Cities (Ministério das Cidades) as such submission might lead to selection bias. The initial objective of the SNIS was to cover municipalities with more than 500,000 inhabitants, so few cities were included in the early years of the sample. This fact can be observed in Table 5, which shows the proportion of municipalities in the SNIS database between 1999 and 2008 by region. The number of municipalities covered by SNIS reached only 70% in 2006. Except for the northern region, Brazilian regions have a similar percentage of municipalities in the database in recent years.

Table 5 - Proportion of Brazilian municipalities in the database by year and region

Year	Brazil	North Region	Northeast Region	Southeast Region	South Region	Midwest Region
1999	10.6%	22.7%	6.4%	12.3%	7.7%	17.0%
2000	17.6%	41.0%	13.8%	19.8%	13.6%	11.8%
2001	27.9%	56.8%	21.4%	27.2%	22.5%	41.8%
2002	31.3%	53.9%	28.6%	27.9%	27.2%	43.1%
2003	35.5%	58.4%	33.9%	31.9%	30.6%	45.7%
2004	44.4%	54.6%	39.9%	39.3%	51.9%	51.1%
2005	50.7%	58.1%	47.0%	51.2%	53.1%	50.2%
2006	78.3%	69.9%	83.1%	72.4%	78.7%	87.6%
2007	76.4%	62.1%	79.9%	73.9%	78.5%	80.3%
2008	74.0%	61.2%	73.0%	74.6%	78.2%	76.6%
Number of Municipalities	5564	449	1793	1668	1188	466

Source: Authors' elaboration

[6] The latest figure available in the SNIS is for the year 2008 and was released in April 2010. In subsequent years, the transmission of sanitation information will become an indispensable requirement for local government access to resources of the Ministry of Cities.

In this case in which the panel is unbalanced, municipalities have both joined and left the sample over the years. As a result, few cities are ever present in the sample. Thus, Table 6 shows the number of municipalities that are present in all years in the sample for the stipulated interval and from which balanced panel data can be formed. From 1999 to 2008, for example, there are 400 municipalities with observations in all these years, which may be called a semi-balanced sample, whereas if we consider the shorter sample between 2005 and 2008, there are 2422 cities with information throughout the period, a total of 9688 observations. We noted that proportionally, the south and southeast regions had higher rates of cities with complete information over time, whereas the northeast region had the fewest municipalities reporting sanitation data on a consistent basis. As there were no representative data for Brazil in 1999 and 2000 because less than 20% of Brazilian municipalities were covered, these years have not been included in the following estimates.

Table 6 - Number of municipalities with sanitation data reported every year by region and time period

Balance	Brazil	North	Northeast	Southeast	South	Midwest
from 1999 to 2008	400	61	81	157	77	24
from 2000 to 2008	695	95	176	247	137	40
from 2001 to 2008	1097	126	269	344	221	137
from 2002 to 2008	1260	140	347	361	270	142
from 2003 to 2008	1465	155	416	424	313	157
from 2004 to 2008	1982	166	535	557	545	179
from 2005 to 2008	2422	194	690	756	586	196
Municipalities	5564	449	1793	1668	1188	466

Source: Authors' elaboration

In addition to the unbalanced data, another complication should be noted: there are several variables missing within the municipal observations. As stated by Saiani (2007), the SNIS is a self-declaring database that is created by basic sanitation service providers filling out questionnaires and forms. Given that there are more than a hundred pieces of information and sanitation indicators for each observation, there may be imperfections in such data, such as erroneous and missing data, caused by unfamiliarity with the requested information, misunderstanding of the questionnaire, or by the

omission of data. Table 7 displays the number of complete observations for each sanitation variable mentioned in Table 2 in the sample for all available municipalities between 2001 and 2008.

Sanitation rates for sewerage, such as sewage collection (in015), sewage treatment (in016), and urban sewerage services (in024), reflect fewer observations because the sewerage system is still incipient in Brazil. In some municipalities, the service provider supplies only water and does not include a sewerage service. Variables with more complete information include water service provision and the rate of water loss. Most indices were incorporated into the SNIS database in 2001, and data on water quality, such as fluoridation and fecal coliform rates, only appear in later years.

Table 7 - Number of complete observations for each sanitation variable, reflecting the complete and unbalanced database

year	2001	2002	2003	2004	2005	2006	2007	2008	Total
in013	1293	1393	1318	2388	2742	4238	4141	3920	21433
in015	211	449	320	733	859	1172	1206	1230	6180
in016	464	536	487	756	859	1111	1224	1216	6653
urwater_service	1454	1731	1703	2459	2815	4305	4218	4080	22765
in024	592	554	507	814	905	1203	1265	1323	7163
in028	1293	1393	1318	2388	2742	4238	4141	3920	21433
in046	203	450	317	753	870	1125	1213	1234	6165
in047	590	554	507	814	905	1200	1263	1323	7156
in049	1291	1396	1317	2390	2738	4242	4140	3925	21439
losses_inc	781	1290	1219	2389	2586	4103	4140	3777	20285
in052	1291	1396	1317	2390	2738	4242	4140	3895	21409
water_service	1462	1733	1704	2460	2818	4318	4219	4081	22795
in056	594	555	507	813	905	1203	1265	1323	7165
fluoridation	0	0	0	2396	2712	4214	4133	3844	17299
nonstantard_clorine	1105	1280	1197	2082	2400	3642	3799	3617	19122
turbidity_inc	1092	1280	1259	2087	2400	3625	3745	3598	19086
in078	1059	1241	0	0	0	0	0	0	2300
in079	1012	1172	1254	2098	2436	3738	3788	3588	19086
in080	865	1013	1273	2089	2298	3711	3751	3559	18559
total_coliform_inc	0	0	1292	2050	2368	3632	3774	3583	16699
in085	0	0	0	2103	2451	3776	3777	3615	15722
in101	0	0	0	1588	1624	3062	2999	2754	12027

Source: Authors' elaboration

Table 8 contains the same data as shown in the previous table but displays only those municipalities that have submitted data for all years of the sample, i.e., the semi-balanced sample. Even with the semi-balanced panel, the sanitation variables still show differences, albeit smaller ones, in the number of observations throughout the period. The number of full sets of annual information for each sanitation variable never exceeds

the total annual observations for this unbalanced sample because for all the sanitation variables, there are some municipalities that lack complete information.

We can also consider a third sample, which has the full balance for each sanitation variable. Table 9 shows the number of municipalities that have full and balanced information for each indicator. The municipalities belonging to each balanced sanitation set are independent because there might be complete data for some sanitation variables and incomplete ones for others in the same municipality. As in the other samples, the variables related to water service have more observations, and sewage indicators have few balanced municipalities. Therefore, three possible samples can be noted: the unbalanced sample, which includes all observations, the semi-balanced sample, which comprises only the municipalities present in all years, and the balanced sample, which includes only cities with complete data for each sanitation indicator.

Table 8 - Number of complete observations for each sanitation variable based on the semi-balanced database[7]

year	2001	2002	2003	2004	2005	2006	2007	2008	Total
in013	927	872	733	1066	1062	1056	1061	1059	7836
in015	166	335	230	426	460	475	466	472	3030
in016	375	412	340	446	460	455	487	467	3442
urwater_service	1036	1090	961	1095	1095	1087	1085	1075	8524
in024	470	421	353	465	474	483	494	497	3657
in028	927	872	733	1066	1062	1056	1061	1059	7836
in046	160	332	227	428	458	457	465	472	2999
in047	469	421	353	465	474	482	493	497	3654
in049	925	872	733	1068	1063	1057	1059	1057	7834
losses_inc	583	812	686	1068	995	1002	1059	1002	7207
in052	925	872	733	1068	1063	1057	1059	1035	7812
water_service	1040	1091	961	1095	1095	1087	1085	1075	8529
in056	471	422	353	464	474	483	494	497	3658
fluoridation	0	0	0	1065	1053	1054	1057	1031	5260
nonstantard_clorine	830	852	706	945	913	934	1009	1008	7197
turbidity_inc	821	852	729	958	915	935	999	1005	7214
in078	800	837	0	0	0	0	0	0	1637
in079	754	760	732	967	938	946	1007	1005	7109
in080	633	633	734	959	870	934	1006	1001	6770
total_coliform_inc	0	0	744	949	926	935	1009	1008	5571
in085	0	0	0	971	958	963	1010	1013	4915
in101	0	0	0	791	689	821	822	779	3902

Source: Authors' elaboration

[7] For loss rates per connection, fluoridation, total coliforms (in085), and cash sufficiency (in101), the sample was considered to be balanced between 2004 and 2008. For nonstandard fecal coliform rates, the period between 2003 and 2008 was used to generate the selection criteria. The same range is considered in Table 9 as follows.

Table 9 - Number of complete observations for each indicator of sanitation based on the balancing of each variable (balanced base) between 2001 and 2008

year	2001	2002	2003	2004	2005	2006	2007	2008	Total
in013	538	538	538	538	538	538	538	538	4304
in015	76	76	76	76	76	76	76	76	608
in016	246	246	246	246	246	246	246	246	1968
urwater_service	871	871	871	871	871	871	871	871	6968
in024	280	280	280	280	280	280	280	280	2240
in028	538	538	538	538	538	538	538	538	4304
in046	71	71	71	71	71	71	71	71	568
in047	209	209	209	209	209	209	209	209	1672
in049	537	537	537	537	537	537	537	537	4296
losses_inc	0	0	0	0	0	0	0	0	0
in052	537	537	537	537	537	537	537	537	4296
water_service	872	872	872	872	872	872	872	872	6976
in056	281	281	281	281	281	281	281	281	2248
fluoridation	0	0	0	0	0	0	0	0	0
nonstantard_clorine	0	0	777	777	777	777	777	777	4662
turbidity_inc	519	519	519	519	519	519	519	519	4152
in078	0	0	0	0	0	0	0	0	0
in079	424	424	424	424	424	424	424	424	3392
in080	318	318	318	318	318	318	318	318	2544
total_coliform_inc	511	511	511	511	511	511	511	511	4088
in085	0	0	0	513	513	513	513	513	2565
in101	0	0	0	958	958	958	958	958	4790

Source: Authors' elaboration

Tables 10 and 11 show the descriptive statistics of dependent variables for the unbalanced and semi-balanced samples. In the two samples, a marked decrease in both children's mortality and morbidity can be observed. The average mortality of children aged one to 12 months, excluding the neonatal period, was 7.4 per thousand live births in the semi-balanced sample in 2001 and declined to 4.8 in 2008. If we include the neonatal period, the decline reached 30% in both samples, indicating the same trend found in the literature. The average decrease in mortality of children aged one to four years is also evident in the period. However, there was no decrease in deaths of children aged five to nine years. From a regional perspective, the infant mortality rate might be converging in Brazil. As noted in Chart 1 in which the sample is considered to be semi-balanced, in 2001, the average infant mortality of 27 deaths per thousand live births in the worst region (the north) was more than 40% above the average of the best rate (16.6 deaths per thousand live births in the southern region). In 2008, the difference between the worst (northeast) and the best (south) regions was less than 30%. This convergence is also found in the rate of infant morbidity. The variations are similar for hospitalizations by age.

Table 10 - Descriptive statistics of dependent variables based on the unbalanced sample

year		hop_diar_inh	hop_diph_inh	hop_tet_inh	hop_tb_inh	hop_chol_inh	hop_hep_inh	hop_trac_inh	hop_pol_inh	hop_dys_inh	hop_ate1_n	hop1_4_n	hop5_9_n	dea_1a12_n	dea_ate1_n	dea1_4_n	dea5_9_n
2001	mean	169.8	0.06	0.52	6.3	0.24	12.9	0.00	0.02	309.7	18.8	28.8	15.2	7.6	21.0	3.6	1.7
	std. dev.	345.2	0.62	2.49	17.0	1.59	22.7	0.11	0.33	460.4	15.9	25.8	15.3	11.3	17.3	5.1	3.6
2002	mean	191.9	0.06	0.41	7.3	0.06	10.3	0.01	0.00	354.3	18.7	29.1	16.0	7.2	19.8	3.7	2.0
	std. dev.	380.0	0.77	2.56	21.6	0.91	16.9	0.16	0.06	491.4	15.3	24.6	16.1	8.6	13.4	5.2	4.2
2003	mean	204.7	0.03	0.36	7.1	0.05	8.7	0.00	0.08	330.9	18.0	28.6	14.8	7.1	19.4	3.7	1.9
	std. dev.	381.4	0.44	1.99	23.0	1.68	15.8	0.03	0.75	446.4	15.0	24.3	13.6	8.0	13.3	5.5	3.4
2004	mean	181.6	0.05	0.30	5.8	0.01	7.7	0.00	0.08	290.7	17.1	25.5	14.4	6.3	18.7	3.3	1.9
	std. dev.	340.4	1.01	1.80	18.4	0.32	14.9	0.00	0.67	405.2	14.8	22.6	13.5	8.5	13.9	5.2	3.6
2005	mean	202.2	0.09	0.29	5.5	0.06	8.5	0.00	0.09	283.2	16.8	24.8	15.0	5.9	17.3	3.0	1.7
	std. dev.	361.2	2.68	2.03	15.9	1.37	15.5	0.05	0.97	424.2	14.9	21.7	14.4	6.7	11.9	4.7	3.3
2006	mean	218.7	0.07	0.22	4.8	0.06	7.4	0.00	0.10	304.2	17.2	27.0	15.4	6.0	17.6	3.1	1.9
	std. dev.	387.0	1.96	1.64	12.7	1.98	14.9	0.04	0.84	506.0	17.0	34.7	17.1	8.4	14.2	5.3	4.3
2007	mean	181.7	0.02	0.22	4.5	0.06	6.6	0.01	0.16	251.2	16.4	26.6	16.6	5.2	16.6	3.3	1.8
	std. dev.	336.9	0.46	1.75	13.6	2.97	14.5	0.32	1.57	420.0	16.0	27.3	19.6	7.2	13.6	7.0	4.2
2008	mean	177.1	0.05	0.15	8.0	0.00	5.7	0.00	0.46	239.1	15.5	21.8	21.8	5.0	15.9	2.9	2.1
	std. dev.	343.0	0.74	1.44	31.3	0.00	11.3	0.14	3.50	416.0	23.3	25.0	25.0	8.0	15.3	6.9	16.2
All	mean	192.2	0.06	0.27	6.0	0.06	7.8	0.00	0.16	285.4	17.0	26.0	16.6	6.0	17.7	3.2	1.9
	std. dev.	359.1	1.38	1.88	20.1	1.75	15.3	0.16	1.73	447.4	17.4	27.0	18.3	8.2	14.2	5.9	7.7

Source: Authors' elaboration with data from DataSUS

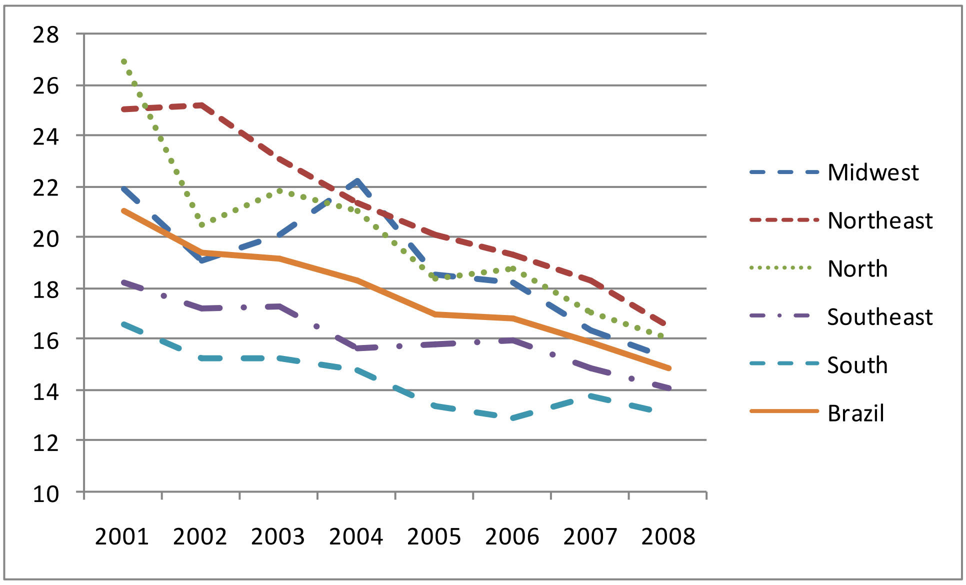
Table 11 - Descriptive statistics of dependent variables based on the semi-balanced sample

year		hop_diar_inh	hop_diph_inh	hop_tet_inh	hop_tb_inh	hop_chol_inh	hop_hep_inh	hop_trac_inh	hop_pol_inh	hop_dys_inh	hop_ate1_n	hop1_4_n	hop5_9_n	dea_1a12_n	dea_ate1_n	dea1_4_n	dea5_9_n
2001	mean	170.0	0.06	0.44	6.3	0.22	12.6	0.00	0.02	310.1	19.4	30.0	16.0	7.4	21.0	3.5	1.7
	std. dev.	344.0	0.62	1.94	16.8	1.30	20.6	0.01	0.39	441.3	15.2	26.0	15.6	12.1	18.1	4.8	3.7
2002	mean	175.0	0.07	0.35	7.8	0.05	9.8	0.00	0.00	321.6	18.5	29.0	16.9	6.8	19.4	3.4	1.9
	std. dev.	354.4	0.88	2.63	25.2	0.49	15.2	0.13	0.06	459.2	13.6	23.5	16.6	8.7	13.1	4.3	3.2
2003	mean	178.7	0.04	0.31	8.1	0.02	8.4	0.00	0.11	301.3	18.2	28.5	15.2	6.8	19.2	3.8	2.0
	std. dev.	326.0	0.50	1.61	28.0	0.31	13.4	0.04	0.79	414.0	14.2	23.1	13.4	8.2	13.5	5.7	3.6
2004	mean	161.5	0.04	0.28	7.9	0.03	8.1	0.00	0.10	255.0	17.5	24.5	14.6	6.0	18.3	3.2	1.8
	std. dev.	304.8	0.50	1.48	25.4	0.48	16.4	0.00	0.72	371.3	14.1	20.6	12.3	9.4	14.7	4.7	2.9
2005	mean	172.6	0.05	0.33	6.9	0.07	8.4	0.00	0.09	250.1	17.5	24.1	14.7	5.7	17.0	2.8	1.7
	std. dev.	316.9	0.84	2.03	18.5	1.80	13.2	0.05	0.65	377.4	13.9	19.5	11.6	5.9	10.6	3.8	2.7
2006	mean	184.5	0.02	0.20	6.6	0.04	8.2	0.00	0.14	251.7	17.8	25.5	14.9	5.3	16.8	3.0	1.8
	std. dev.	337.7	0.19	1.05	17.2	0.48	13.9	0.07	1.06	406.1	15.1	21.0	12.3	6.1	10.6	3.8	3.0
2007	mean	153.2	0.02	0.24	6.0	0.02	7.8	0.02	0.20	209.4	17.1	24.5	15.1	5.3	15.9	3.3	1.8
	std. dev.	309.3	0.32	1.72	19.5	0.31	14.4	0.61	1.52	349.1	13.3	19.2	13.6	5.7	9.6	6.2	3.4
2008	mean	139.9	0.12	0.17	8.8	0.00	6.2	0.02	0.53	200.8	14.9	20.1	20.1	4.8	14.8	2.7	1.7
	std. dev.	271.2	1.17	1.39	32.0	0.00	10.4	0.27	2.56	333.1	11.9	18.4	18.4	5.1	8.5	3.8	2.9
All	mean	166.9	0.05	0.29	7.3	0.06	8.7	0.01	0.15	262.5	17.6	25.8	15.9	6.0	17.8	3.2	1.8
	std. dev.	321.7	0.70	1.79	23.4	0.86	15.1	0.24	1.22	398.1	14.0	21.7	14.5	8.0	12.8	4.7	3.2

Source: Authors' elaboration with data from DataSUS

There was a marked decrease in hospitalizations for children up to one year of age (approximately 20%) and between one and four years of age (decrease of approximately 30%) compared with the number of live births. However, the rate of hospitalizations for children aged five to nine years remained stable in the semi-balanced sample, whereas the variable showed growth in the unbalanced sample.

Chart 1- Variation of the average infant mortality rate in deaths per live births in Brazilian regions between 2001 and 2008



Source: Authors' elaboration, DataSUS

In terms of hospitalizations by disease, distinct changes can be observed. Although there was a clear decrease in hospitalization rates for tetanus, cholera, hepatitis, and dysentery for every hundred thousand inhabitants, there was an effective increase in the rate of hospitalizations for polio. For other diseases, there are specific variations in a few years of the samples, indicating bursts of morbidity, and there are significant differences in each sample so that it is not possible to ascertain a tendency for the variations. The reduction in the variance of health data should also be noted when studying a more balanced sample as the number of observations is reduced.

Table 12 details according to each type of sample the descriptive statistics for the control variables described in Table 4. An increase may be observed over time in the proportion of beneficiaries of municipal family health programs and municipal per capita GDP. The population variable shows the difference between the unbalanced and semi-balanced samples. Initially, the average population of municipalities begins to

decrease in some years due to the inclusion of smaller municipalities in the sample. In the second sample, the population follows its expected positive change with the exception of 2007 as the population was counted by the IBGE in that year, resulting in a reduction of the estimates made in previous years. With regard to the proportion of people enrolled in the Family Health Program, sharp growth can be observed over the years, with more intensity in the north and northeast regions. Immunization coverage of inhabitants in the municipalities shows a decrease in both samples.

Table 12 - Descriptive statistics for control variables based on the unbalanced (1) and semi-balanced (2) samples

ano		psfpcap		vacc_cov		pop		Gpdpc	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
2001	mean	0.63	0.61	83.1	83.2	75,396	91,747	5.6	5.7
	std. dev.	0.36	0.36	13.5	12.9	343,910	405,552	6.8	5.2
2002	mean	0.70	0.66	79.3	79.3	70,889	93,082	6.1	6.6
	std. dev.	0.35	0.35	9.6	9.8	330,262	409,667	7.4	6.1
2003	mean	0.73	0.69	75.3	75.5	65,020	94,399	7.2	7.9
	std. dev.	0.33	0.34	8.3	8.2	312,198	413,185	8.1	7.4
2004	mean	0.76	0.70	75.8	75.7	56,864	97,168	7.9	8.7
	std. dev.	0.33	0.33	9.0	8.8	286,527	420,600	9.0	8.3
2005	mean	0.80	0.72	73.2	73.0	53,260	98,702	7.9	9.3
	std. dev.	0.32	0.33	7.9	7.5	271,361	424,708	8.6	9.1
2006	mean	0.85	0.74	86.0	84.3	39,502	100,208	8.1	10.1
	std. dev.	0.31	0.33	11.0	9.6	221,757	428,794	9.0	10.1
2007	mean	0.85	0.78	86.1	84.9	39,443	98,903	9.3	11.5
	std. dev.	0.32	0.39	11.0	9.3	222,669	426,259	10.6	10.9
2008	mean	0.84	0.76	82.2	81.6	40,934	101,441	10.6	12.7
	std. dev.	0.32	0.32	10.5	9.0	228,944	430,867	10.6	12.2
Total	mean	0.80	0.71	81.1	79.7	50,170	96,956	8.3	9.1
	std. dev.	0.33	0.35	11.3	10.4	263,849	419,890	9.4	9.2

Source: Authors' elaboration

We will now examine statistics for sanitation indicators. Due to the range of variables involved, it was decided to evaluate them in different blocks. The first block is related to indicators of access to water: urwater_service (urban water service), in052 (water consumption rate), and water_service (total water service). Table 13 shows each variable with statistics for the three samples: the unbalanced sample (column 1), the semi-balanced sample (column 2), and the fully balanced sample (column 3). Note that access to water in urban areas tends to be universal in Brazilian municipalities. The rate of water consumption is the ratio between the volume of water consumed and the amount of water produced; thus, this value's slight decrease is expressed in the expansion of the denominator for that rate. For total water service, note the deceleration

in the growth of this rate for the decades prior to the universalization of access.

Rates of access to water vary by region. Surprisingly, the midwest has the highest levels of water provision in cities, reaching an average of 79.2% of the population (unbalanced sample). The southeast has municipalities with an average water provision of 76.6%, whereas the south has 65.7%. The north and northeast regions have an average access of 54.2% and 53.8%, respectively. The states with the highest municipal average of this indicator are Mato Grosso do Sul (86.9%) and São Paulo (83%), whereas those with the lowest averages are Amapá (36.9%) and Pará (36.2%). A similar situation appears for urban water services. In the midwest, southeast, and south, the average of this variable is approximately 95%; in the northeast, the average is 86.2%, and in the north, it is 80.3%. The variations in the average of this index for Brazilian regions can be observed in Chart 2.

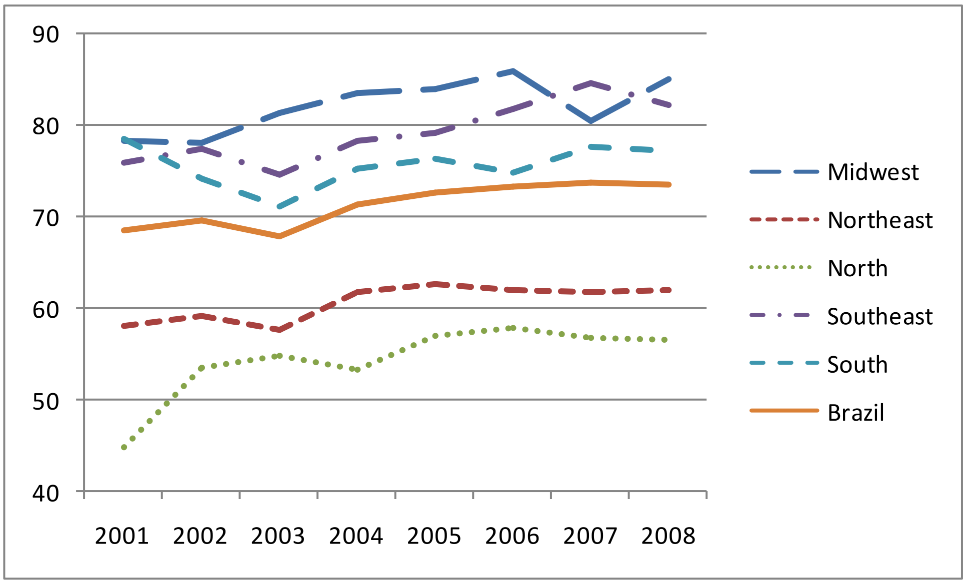
The second block covers sanitation indicators related to production inefficiency variables. Included in this block are variables in013 (revenue loss rate), which considers the total water available for distribution and not billed, in028 (water revenue rate), which is the ratio between the volume of water billed and produced, in049 (distribution loss rate), which is the difference between the volume of water produced and consumed in relation to the total produced, losses_inc, which reports the volume of losses by the

Table 13 - Descriptive statistics of access to water indicators based on the unbalanced (1), semi-balanced (2), and balanced (3) samples

year		urwater_service			in052			water_service		
		(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
2001	mean	86.4	88.6	87.9	65.7	64.5	62.7	65.3	68.6	65.6
	std. dev.	20.5	17.9	17.9	39.2	27.6	19.5	26.5	25.4	25.3
2002	mean	87.6	89.1	88.8	63.1	61.9	60.4	65.6	69.6	67.8
	std. dev.	18.4	16.7	16.3	31.1	18.4	18.1	25.6	25.0	24.6
2003	mean	89.3	90.0	90.6	61.9	62.8	60.2	63.3	67.9	68.8
	std. dev.	19.0	18.1	17.3	23.9	23.8	17.7	25.5	25.3	24.9
2004	mean	91.7	91.0	90.7	65.1	62.1	60.6	66.5	71.4	69.6
	std. dev.	16.7	17.0	17.1	22.7	18.5	17.8	24.8	24.7	24.5
2005	mean	92.9	92.1	91.8	65.4	62.2	60.0	67.0	72.6	70.8
	std. dev.	15.0	15.3	15.3	19.5	18.2	18.0	24.4	24.0	23.8
2006	mean	92.6	91.9	91.1	66.8	62.9	60.4	64.3	73.2	71.1
	std. dev.	15.9	16.0	16.7	20.0	19.5	20.1	25.1	24.1	24.1
2007	mean	91.8	91.1	90.1	66.0	62.4	59.8	65.3	73.8	71.5
	std. dev.	16.1	17.2	18.1	20.1	17.6	18.1	25.0	24.5	24.4
2008	mean	91.5	90.7	89.8	66.7	62.2	59.3	65.6	73.5	71.8
	std. dev.	16.3	16.9	17.4	20.8	17.7	18.2	24.7	24.3	24.4
Total	mean	91.2	90.6	90.1	65.7	62.6	60.4	65.4	71.4	69.6
	std. dev.	16.9	16.9	17.1	23.1	20.2	18.5	25.1	24.7	24.6

Source: Authors’ elaboration

Chart 2 - Variation in the average rate of access to water in Brazilian regions between 2001 and 2008 according to the semi-balanced sample



Source: Authors' elaboration

quantity of active water connections, and in101 (cash sufficiency rate), which is a financial variable that measures the relationship between revenues and expenditures of sanitation companies in the municipalities.

Descriptive statistics of the indicators for this block are shown in Table 14. Brazilian inefficient production data show a high rate of water supply loss in relation to the rest of the world. It is clear that reduction in inefficiency has not been the focus of public action as these indices have shown little or no improvement in the last decade. This finding is most noticeable in Chart 3, which is based on the semi-balanced sample and reports the variation in the average loss rate among regions of the country. According to the unbalanced sample, the rate of revenue loss over the years differs among regions of the country; in 2008, the average for this rate reached 21.4% in the south and 23.2% in the southeast. In the northeast region, the average was 34.2%. In some sanitation companies of the north and northeast regions, the revenue loss rate of water exceeds 70%.[8] Conversely, the average cash sufficiency rate for sanitation companies in the cities remained relatively constant since 2004, during a period of national economic growth.

[8] See Simão (2011).

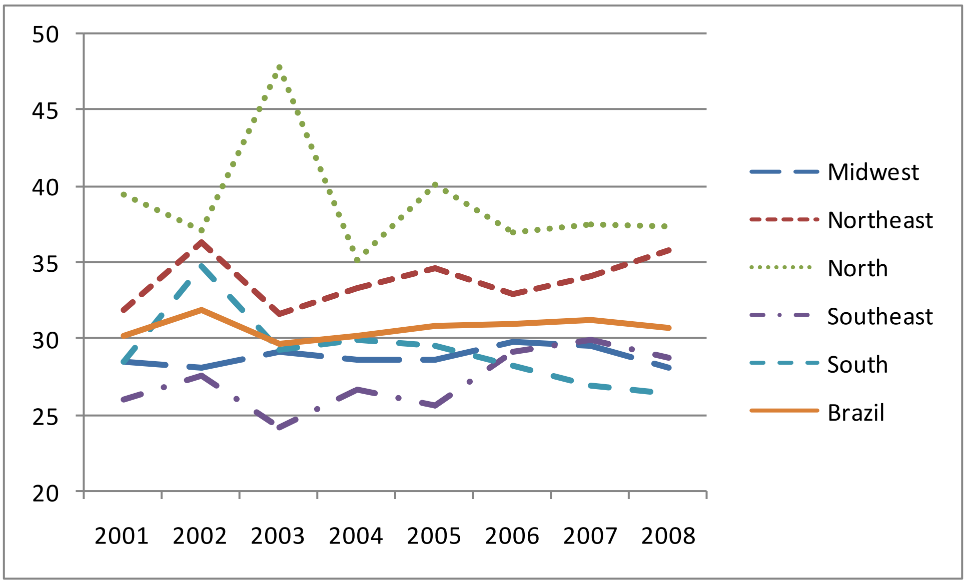
Table 14 - Descriptive statistics of production inefficiency indicators based on the unbalanced (1), semi-balanced (2), and balanced (3) samples[9]

year		in013			in028			in049			losses_inc			in101		
		(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
2001	mean	29.8	30.2	32.0	70.2	69.8	68.0	34.3	35.5	37.3	300.3	315.5		.	.	.
	std. dev.	40.5	31.4	22.3	40.5	31.4	22.3	39.2	27.6	19.5	258.4	247.4		.	.	.
2002	mean	30.7	31.9	33.3	69.2	68.1	66.7	36.9	38.1	39.6	295.9	312.3		.	.	.
	std. dev.	36.1	21.4	21.1	36.2	21.4	21.1	31.0	18.4	18.1	224.4	221.0		.	.	.
2003	mean	30.4	29.7	34.0	69.6	70.3	66.0	38.1	37.2	39.8	280.7	288.1		.	.	.
	std. dev.	27.8	28.2	21.3	27.8	28.2	21.3	23.9	23.8	17.7	214.1	207.5		.	.	.
2004	mean	26.1	30.2	33.4	73.9	69.8	66.6	34.9	37.9	39.4	327.2	390.0		102.4	108.2	107.5
	std. dev.	28.2	22.9	21.2	28.2	22.9	21.2	22.7	18.5	17.8	479.3	536.8		55.2	52.6	48.5
2005	mean	26.8	30.8	34.2	73.2	69.2	65.8	34.6	37.8	40.0	247.9	296.9		95.7	98.3	98.4
	std. dev.	24.7	21.9	22.3	24.7	21.9	22.3	19.5	18.2	18.0	207.7	215.5		47.9	52.5	48.6
2006	mean	26.1	31.0	35.5	73.9	69.0	64.5	33.2	37.1	39.6	235.0	295.0		98.9	104.5	101.6
	std. dev.	26.7	23.8	24.6	26.7	23.8	24.6	20.0	19.5	20.1	203.4	224.4		62.7	65.4	50.9
2007	mean	26.3	31.2	36.3	73.7	68.8	63.7	34.0	37.6	40.2	301.3	385.9		111.3	137.9	105.4
	std. dev.	23.0	20.3	19.0	23.0	20.3	19.0	20.1	17.6	18.1	571.7	844.7		419.2	793.1	58.3
2008	mean	25.9	30.8	36.9	74.1	69.2	63.1	33.4	37.8	40.7	230.8	293.7		102.5	103.3	102.3
	std. dev.	25.3	21.6	20.2	25.3	21.6	20.2	20.8	17.5	18.2	198.4	213.7		56.6	46.3	43.1
Total	mean	27.0	30.7	34.5	73.0	69.3	65.5	34.3	37.4	39.6	269.4	325.5		102.9	111.0	103.0
	std. dev.	27.6	23.9	21.6	27.6	23.9	21.6	23.1	20.2	18.5	353.2	428.3		215.1	367.3	50.2

Source: Authors' elaboration

[9]The losses_inc variable did not show observations in which there would be complete balancing of this indicator in each year in the sample; therefore, there are no values in that column (3). Cash sufficiency rate data (in101) only exist since 2004.

Chart 3 - Variation in the average for the revenue loss rate in Brazilian regions between 2001 and 2008 based on the semi-balanced sample



Source: Authors' elaboration

The third block refers to sanitation indicators. This block contains the following variables: in015 (sewage collection rate), in016 (sewage treatment rate), in024 (urban sewage service rate for municipalities served with water), in046 (treated sewage rate for water consumed), in047 (urban sewage service rate for municipalities served by sewage), and in056 (total sewage service rate for municipalities with water service). Table 15 shows the descriptive statistics of variables in this block according to each sample type.

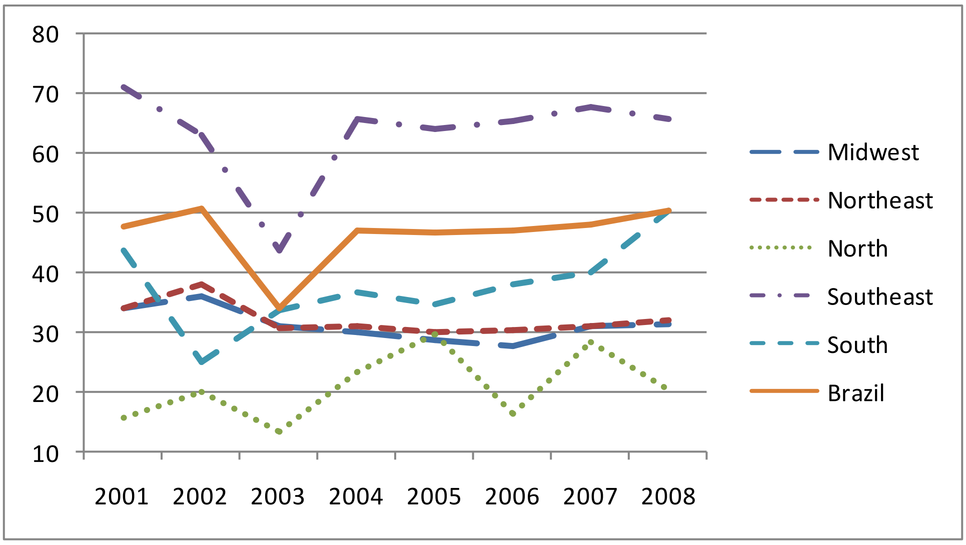
The expansion of sewage services in the country was minimal, occurring at a slower rate than the rates of access to water even though access to water began from lower levels. According to the unbalanced sample, the regional distribution of the sewage collection rate in 2008 shows that the southeast region had the best indicators with an average of 67.3% coverage of sewage collection. The south, midwest, northeast, and north had a municipal average coverage of 44.3%, 33.6%, 30.8%, and 25.7% in the unbalanced sample, respectively. Water treatment had a higher average coverage in the northeast, south, and midwest regions, and surprisingly, the southeast had the worst rates in the three samples. It should be noted that sanitation block variables are more likely to suffer from selection bias because of their small number of observations. There is great variance in the observations of the sewage treatment rate (in016) because in all

the years of the sample, more than 10% of the observations of this indicator were zero, whereas more than half of the observations reached 100% of the population in the municipality. The improvement of the other indicators of sewage over time was somewhat better.

Based on the semi-balanced sample, chart 4 shows the annual variation of sewage collection in Brazilian regions during the 2000s. It would appear that none of these regions had an average rate exceeding 70%; however, the improvement over the sample is slight with the exception of the south region. The problem of erroneous data may be observed in variables in this block. Approximately 1% of the variables for the collection and treatment of sewage report a degree of coverage of more than 100%, suggesting erroneous information provided by the sanitation companies that has not been corrected in the database. These erroneous data may explain the unexpected decline of this rate in 2003, particularly in the midwest region.

The next block contains variables that measure water quality: fluoridation (the rate of water fluoridation), nonstandard_chlorine (the incidence of the analyses of nonstandard residual chlorine), turbidity_inc (the incidence of non-standard residual chlorine analysis), in078 (the incidence of nonstandard fecal coliform analysis),

Chart 4 - Variation in average rate of sewage collection in Brazilian regions between 2001 and 2008 based on the semi-balanced sample



Source: Authors' elaboration

Table 15 - Descriptive statistics of sewage based on the unbalanced (1), semi-balanced (2), and balanced (3) samples

year		in015			in016			in024			in046			in047			in056		
		(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
2001	mean	47.3	47.7	33.9	66.4	67.0	74.1	44.7	45.1	47.2	24.7	25.9	27.8	44.8	45.3	47.4	39.7	40.1	40.8
	std. dev.	39.1	39.8	30.5	51.1	43.4	40.0	37.6	37.4	34.3	32.7	34.1	26.5	38.0	37.8	34.3	34.6	34.6	30.7
2002	mean	50.1	50.8	34.5	64.4	66.3	78.9	52.4	52.7	48.5	26.1	26.8	31.5	53.0	52.9	48.9	46.2	47.1	42.1
	std. dev.	31.2	31.4	30.7	45.8	45.7	40.7	35.7	35.4	34.6	29.7	29.8	28.9	36.3	35.7	34.9	33.0	33.1	31.0
2003	mean	32.4	34.2	34.4	69.7	70.5	72.8	47.0	46.1	50.3	22.5	23.7	28.4	47.0	46.1	50.5	39.1	39.2	42.6
	std. dev.	27.7	28.1	29.0	56.4	61.2	38.0	35.9	35.2	35.3	24.4	24.6	26.2	35.9	35.2	35.3	31.3	31.1	31.3
2004	mean	46.6	47.2	34.3	69.0	69.1	80.9	52.3	52.3	51.0	28.2	29.2	30.4	52.3	52.3	51.2	43.1	45.2	43.0
	std. dev.	30.9	31.2	29.5	45.6	46.7	44.5	35.7	36.2	34.3	28.5	29.0	28.4	35.7	36.2	34.3	32.1	32.9	30.2
2005	mean	47.4	46.6	35.1	70.3	70.5	81.9	55.2	53.2	52.2	30.0	29.7	33.1	55.2	53.3	52.4	45.5	45.9	44.1
	std. dev.	30.0	30.4	29.7	45.4	45.4	41.1	36.1	36.1	34.3	29.8	28.9	30.3	36.1	36.1	34.3	32.7	32.8	30.2
2006	mean	50.7	47.0	35.8	75.3	75.7	83.5	60.0	53.7	53.1	35.3	32.5	34.8	59.9	53.6	53.2	48.0	46.3	44.9
	std. dev.	29.4	30.1	28.1	40.7	39.1	35.0	36.0	36.1	34.5	30.5	28.7	27.5	36.0	36.1	34.5	32.4	32.9	30.5
2007	mean	52.7	48.2	34.0	72.8	75.1	85.8	61.7	54.1	54.2	35.5	33.1	33.8	61.7	54.4	54.4	51.1	47.8	47.1
	std. dev.	30.7	30.3	26.1	41.9	38.9	30.5	35.8	35.9	34.6	31.7	28.9	25.6	35.8	35.8	34.6	33.0	33.3	31.3
2008	mean	54.3	50.3	35.6	71.9	75.9	87.0	61.7	53.9	54.6	36.7	35.2	34.6	61.7	53.9	54.8	50.1	47.3	47.4
	std. dev.	39.1	50.2	29.9	42.4	39.1	30.1	35.8	35.9	34.2	36.0	39.2	25.5	35.8	35.9	34.2	32.6	33.3	30.9
Total	mean	49.8	47.2	34.7	70.9	71.5	80.6	56.3	51.6	51.4	32.3	30.5	31.8	56.4	51.7	51.6	46.6	45.1	44.0
	std. dev.	32.8	35.0	29.1	45.0	44.9	38.0	36.4	36.2	34.6	31.7	31.0	27.3	36.5	36.3	34.6	32.9	33.2	30.8

Source: Author’s elaboration

in079 (the conformity rate of the number of samples - residual chlorine), in080 (the conformity rate of the number of samples - turbidity), total_colif_inc (the incidence of nonstandard total coliform analyses), and in085 (the conformity rate of the number of samples - total coliforms). The variables on the incidence of residual chlorine analysis, turbidity, fecal coliform, and the non-standard total were calculated as the ratio between the quantity of samples for analysis with nonstandard results and the number of samples analyzed for the measurement of these variables. The water fluoridation rate is the ratio between the volume of water and the total produced and processed, and the conformity rates of the quantities of residual chlorine and turbidity samples are calculated as the percentage ratio of the quantity of samples analyzed for measurement, which appears in the denominator of the incidence of these variables, and the minimum quantity of sample required for these analyses. Descriptive statistics of these indicators are shown in Table 16.

For most indicators, there is a reduction in values over time, suggesting an improvement in water quality with the exception of turbidity, which remained almost constant during the last decade, and the incidence of nonstandard total coliform, which only has results for the first two years of the sample. Figure 5 shows the variation of the average incidence of fecal nonstandard coliform (colif_total_inc) among Brazilian regions based on the semi-balanced sample. Some convergence between the indicator values in recent years can be observed. However, the south, southeast, and midwest regions in that order continue to show the best indicators of basic sanitation in the country.

It is worth noting that the statistics cited are reported at municipal levels. Data for the national level do not necessarily coincide with those presented here because some municipalities lack information, which can cause bias in relation to national statistics, and the statistics cited in the present study are not weighted by total municipal population. Thus, small municipalities, with perhaps the worst sanitation and health data, are over-represented in these samples, whereas large centers are underrepresented. For the national level, therefore, the changes observed in the data shown in the present study probably under-represent the variation for the country as a whole over the last decade. Nonetheless, this analysis is useful to observe the heterogeneity of basic sanitation in the country and its variations and to convey the focus of the present study to the municipalities.

Table 16 - Indicators of water quality statistics[10] based on the unbalanced (1), semi-balanced (2), and balanced (3) samples

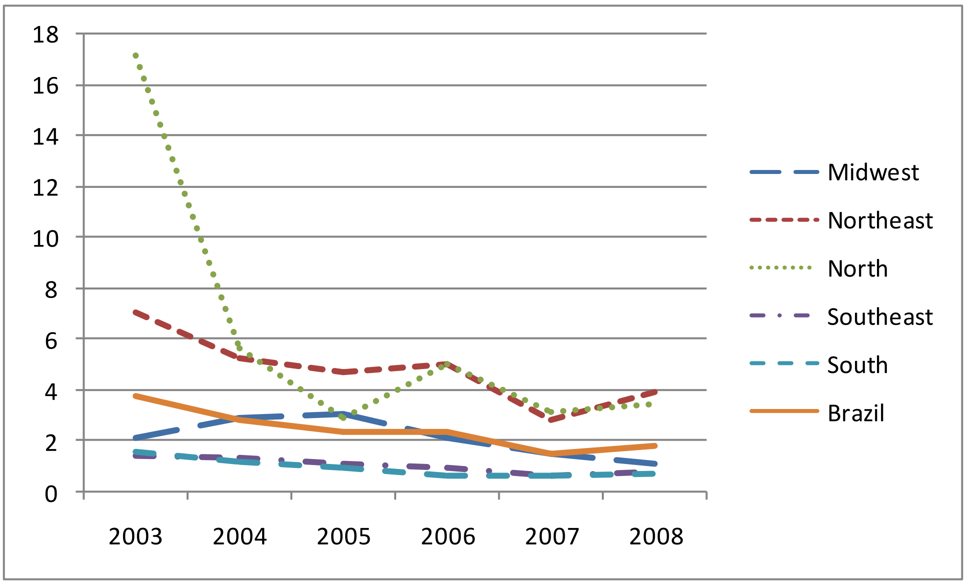
year		fluoridation			nonstandard_chorine			turbidity_inc			in078		
		(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
2001	mean	.	.	.	5.8	5.4	4.9	5.8	5.2	5.0	3.7	3.2	
	std. dev.	.	.	.	14.8	13.6	11.0	15.0	13.9	12.2	11.8	10.0	
2002	mean	.	.	.	4.7	4.1	4.4	5.0	4.6	4.5	3.1	3.0	
	std. dev.	.	.	.	10.3	9.4	9.5	11.3	9.8	9.7	9.1	8.7	
2003	mean	.	.	.	5.7	5.1	4.0	9.1	7.5	5.5	.	.	
	std. dev.	.	.	.	13.7	12.0	8.6	18.4	16.4	12.5	.	.	
2004	mean	56.5	56.0	63.7	3.4	4.0	3.8	6.4	6.4	6.7	.	.	
	std. dev.	48.6	48.4	47.0	9.4	10.2	7.8	14.7	14.2	14.7	.	.	
2005	mean	57.5	56.9	64.5	5.2	4.5	4.8	4.9	4.9	5.3	.	.	
	std. dev.	48.5	48.3	46.8	15.0	13.6	11.6	13.3	12.7	12.8	.	.	
2006	mean	55.5	57.5	64.7	4.3	4.0	3.8	5.6	5.2	5.4	.	.	
	std. dev.	49.0	48.3	46.8	13.2	12.3	9.7	13.8	12.5	12.0	.	.	
2007	mean	60.2	59.8	66.1	3.1	2.7	3.6	5.4	5.3	5.9	.	.	
	std. dev.	47.4	47.1	46.0	9.0	7.6	8.9	13.2	12.3	12.8	.	.	
2008	mean	64.2	61.2	65.8	2.8	3.0	3.7	6.0	6.0	6.6	.	.	
	std. dev.	47.0	47.4	46.3	8.5	8.6	9.2	13.7	13.5	14.7	.	.	
Total	mean	59.0	58.3	65.0	4.0	4.0	4.1	5.8	5.6	5.6	3.4	3.1	
	std. dev.	48.1	47.9	46.6	11.5	11.0	9.6	14.0	13.2	12.8	10.4	9.4	

year		in079			in080			total_colif_inc			in085		
		(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
2001	mean	170.2	167.0	165.3	253.2	252.7	238.8	.	.	.	.	.	.
	std. dev.	175.5	167.8	156.7	251.8	251.9	242.2	.	.	.	.	.	.
2002	mean	174.7	182.9	178.8	235.8	232.6	242.9	.	.	.	.	.	.
	std. dev.	193.7	191.1	185.4	247.1	237.3	254.6	.	.	.	.	.	.
2003	mean	135.9	121.2	115.6	123.7	133.8	116.5	4.2	3.7	3.2	.	.	.
	std. dev.	145.7	108.1	87.8	126.7	127.7	104.6	10.9	9.9	8.1	.	.	.
2004	mean	118.1	125.1	103.0	120.7	140.3	88.5	2.8	2.8	2.8	110.2	110.4	116.3
	std. dev.	129.8	121.6	91.4	150.4	155.7	83.2	7.8	6.7	7.4	91.6	94.4	97.8
2005	mean	135.0	127.8	130.4	111.8	119.5	116.5	2.7	2.3	2.2	93.8	92.3	99.7
	std. dev.	133.4	117.5	125.7	113.3	110.9	95.4	8.1	6.3	4.4	55.6	57.8	51.5
2006	mean	121.9	124.0	120.4	133.6	158.5	200.5	2.2	2.3	1.9	103.5	102.5	113.9
	std. dev.	94.9	88.5	62.4	119.4	149.7	175.8	8.4	7.6	5.2	60.8	63.0	63.7
2007	mean	138.5	134.3	115.5	148.8	171.5	210.8	1.5	1.5	1.4	112.4	112.6	120.3
	std. dev.	312.1	275.3	60.6	252.1	225.2	180.5	5.4	4.5	3.8	165.6	140.4	226.1
2008	mean	136.7	136.5	148.3	133.8	156.0	210.6	1.9	1.8	1.7	101.8	101.0	109.4
	std. dev.	111.2	112.5	121.3	119.4	144.8	184.7	6.2	4.9	4.2	46.5	48.6	45.4
Total	mean	136.0	138.5	134.6	143.0	165.5	178.1	2.3	2.4	2.2	104.6	103.8	111.9
	std. dev.	181.9	160.8	121.4	176.7	182.5	184.9	7.5	6.7	5.8	98.1	88.2	118.0

Source: Authors' elaboration

[10] The fluoridation rate and in085 (the conformity rate of the number of samples - total coliforms) have data reported by the SNIS only from 2004. The balanced sample of these variables refers to the period between 2004 and 2008. The in078 (incidence of nonstandard total coliform analyses) has data only until 2002, resulting in no observations in the completely balanced sample. Data for the incidence of total nonstandard coliform began in 2003, with the balanced period between 2003 and 2008.

Chart 5 - Variation in the average incidence of non-standard fecal coliform in Brazilian regions between 2001 and 2008 based on the semi-balanced sample



Source: Authors' elaboration

Regulatory aspects of the SNIS database should also be noted. Of the 4610 municipalities in the unbalanced sample of the 2008 SNIS, 3480 (75.49%) had sanitation services provided by joint stock companies with public administration, such as the Sanitation Company of São Paulo (Compania de Saneamento do Estado de São Paulo – Sabesp), which covers 364 municipalities and the former state sanitation companies; moreover, 344 (7.46%) municipalities had sanitation services provided by joint stock companies with private management, 340 (7.36%) by local authorities, 243 (5.27%) by direct public administration of the sector, and 179 (3.88%) had private companies performing such services. With regard to these companies' coverage in the cities, 3962 (85.94%) had a regional scope, such as the state companies, 20 (0.43%) had microregional coverage encompassing two or more municipalities, usually connected by the same river basin, whereas 567 listed municipalities (13.25%) had local sanitation companies, essentially the municipalities themselves and direct public administration.

4. Model and Results

4.1. Model

Our goal is to identify whether there is indeed a direct relationship between improved quality and access to sanitation and people's health in the municipalities.

Through this inquiry, the present article proposes to examine the possible effects of sanitation policies in this decade on the health indicators described above. The idea is to capture these effects through a strategy of panel data estimation using fixed effects.

The reason for using this model is to attempt to identify more precisely the effect of the sanitation variable on health with the municipality as the unit of observation. For this model to function, the advancement of sanitation must not be correlated with other factors that affect citizens' health, as indicated in Watson (2006). The inclusion of the municipality's fixed effects is therefore essential because states of health may depend on unobservable variables that are intrinsic to each location and fixed over time. For example, cities may have localized cases of air and sea pollution, flooding in rivers, varying degrees of rainfall, or levels of education and culture that enhance sanitation and healthcare. However, including these effects does not control for effects of possible time-varying characteristics relating to the progress of sanitation.

Likewise, it is important to include fixed time effects to identify characteristics correlated with health that change over the years. These effects capture the common effects of each time period that may impact municipalities. With these considerations, a specification was developed for the model as detailed in the equation below:

$$HealthInd_{it} = \beta_0 + \beta_1 WaterInd_{it} + \beta_2 Controls_{it} + a_i + \delta_t + u_{it} \qquad (5),$$

in which i is the municipality in question, t is the year used in the sample, a_i is the vector of the municipality's fixed effects, and δ_t is the vector of fixed time effects.

To estimate the fixed effects for this equation, some assumptions must be accepted, in accordance with Wooldridge (2002). The first assumption is the strict exogeneity of the error term, i.e., it is assumed that the variables of interest are not correlated with unobserved components, which would cause a bias in the estimated coefficients. The second assumption is that the relevant variables must have time variations, which is the case in this model.

In this database, existing sanitation indicators vary across years. One relevant issue is the acceptance of the assumption of strict exogeneity. As stated in the studies of Alves and Beluzzo (2004) and Soares (2007), municipalities with high infant mortality rates tend to have citizens who have worse living conditions, and these municipalities

may be more likely than others to suffer the impact of public policies relating to healthcare, education, and sanitation. This fact could cause endogeneity by double causality in the sense that health indicators would lead to investment and change in sanitation. However, public sanitation policies implemented over the last decade did not consider health data for investments in the sector. The limitation of these missing variables hinders the use of dynamic panel techniques as using lagging variables can increase the selection bias by reducing the number of observations.

There are also limitations of the data due to the imbalance and omission of missing variables, which also hinders the adoption of lagged explanatory variables, as observed by Watson (2006). In the present article, sanitation investments budgeted and completed three years before the computation of the dependent variable were the most significant lag in reducing infant mortality. As the sanitation variable from the SNIS database is the result of sanitation investments that have already occurred in the country, and as indicators of water quality tend to have a more immediate effect on the health of citizens, we have considered this adoption only for health control variables that have more complete data.

4.2. Results

Calculations were performed using the variables described in Section 3. The calculations reported in the present study are those we considered to be the most consistent. We are faced in this case with the dilemma that as more sanitation variables are incorporated in the vector $IndicWater_{it}$, the number of observations used in the calculation decreases because there are few municipalities with complete information, as previously reported. Thus, we prioritized the inclusion of explanatory indicators in this vector for each sanitation block so that the different effects could be verified. The semi-balanced sample was used to address various indicators, and to decrease bias, the sample period between 2005 and 2008 was used.

4.2.1. Mortality and Morbidity

The initial results are shown in Table 17. The sanitation indicators vector includes the provision rate (water_service) in the access to water block, the collection rate (in015) and sewage treatment (in016) in the sanitation block, the distribution loss rate in the inefficiency of production block, and residual chlorine indicators, turbidity, and

nonstandard total coliforms in the water quality block. The vector $Controls_{it}$ is composed of all the variables described in Table 2.

Table 17 - Calculations of fixed effects using deaths by age per thousand live births as the dependent variable

	Dependent Variable			
	dea_ate1_n	dea_1a12_n	dea1_4_n	dea5_9_n
water_service	0.005	0.013	0.022*	-0.001
	(0.030)	(0.017)	(0.012)	(0.015)
sewage_conection	0.025	-0.007	0.004	0.009*
	(0.017)	(0.008)	(0.009)	(0.005)
sewage_treatment	0.017**	0.005	-0.001	-0.003
	(0.008)	(0.006)	(0.003)	(0.003)
loss rate	-0.038	-0.006	0.027**	-0.026
	(0.037)	(0.020)	(0.013)	(0.021)
nonstantard turbidity rate	-0.049*	-0.015	-0.006	-0.006
	(0.029)	(0.011)	(0.012)	(0.009)
nonstantard turbidity rate	-0.026	-0.017	-0.014	-0.003
	(0.021)	(0.021)	(0.016)	(0.005)
nonstantard total coliform rate	0.124**	0.024	0.047*	0.013
	(0.063)	(0.029)	(0.028)	(0.021)
population	YES	YES	YES	YES
% PSF	YES	YES	YES	YES
GPD per capita	YES	YES	YES	YES
vacination coverage	YES	YES	YES	YES
educ up tp 4 years	YES	YES	YES	YES
year dummies	YES	YES	YES	YES
observations	1,668	1,668	1,668	1,668
R2	0.037	0.028	0.018	0.036

Obs: *** p<.01, ** p<.05, * p<.1

Source: Authors' elaboration

We can observe that the coefficients of the sanitation variable related to access to water and sewage have little statistical significance and that even the coefficient sign was unexpected for deaths in older age groups. This result, however, is in accordance with the literature for two reasons: first, the expansion of access to sanitation in Brazil occurred mainly in the 1970s and 1980s, so its impact on health data tends to reduce over time; second, there is evidence found in studies that sanitation must be accompanied by other public policies to have an impact on child health. The production inefficiency and water quality coefficients, however, show mostly satisfactory results. For example, in the case of the incidence of nonstandard fecal coliforms, a 1%

reduction in these cases suggests a decline of 0.12 deaths of children less than one year of age, including the neonatal period, for every thousand live births.

Table 18 contains calculations in which the dependent variables consist of hospitalizations by age. Again, we find unexpected results for water provision, although there is evidence of a significant effect of water quality through residual chlorine. Sanitation variables have the expected coefficient sign but are insignificant for all ages, whereas the coefficient of the distribution inefficiency indicator has an unexpected sign. This finding reduces the possibility that the impact of production inefficiencies variables on health indicators also occurs in an indirect way by increasing access to water.

Calculations involving hospitalizations by type of disease listed in Table 3 are listed in Table 19. First, note the low economic significance of the sanitation variables as the dependent variables are calculated in relation to a group of one hundred thousand inhabitants. There are two reasons for this figure: the low number of certain diseases in the country, such as diphtheria, tetanus, polio, and cholera, with the last two near eradication, and the fact that these diseases are diagnosed and reported in a hospital or health center only when they reach a serious stage. Thus, the effect of sanitation would be greater on prevention than on a decrease in critical events. Nonetheless, we find the expected effect of water treatment on the reduction of dysentery and diphtheria. We find no evidence of the impact of sanitation and distribution losses on these diseases, whereas water quality rates have disparate results for every type of disease.

4.2.2. Segmentation of the Sample

Calculations were performed for different population levels and income. With regard to the population, larger cities should have greater scale and resource capacity for the implementation of sanitation services but may have more difficulty in universalizing the provision of water, differentiating them from the smaller cities. The observed level of income may determine different pathways for the impact of sanitation. Thus, we performed new calculations for population quartiles and municipal GDP per capita. The extreme quartiles of the two variables can be observed here, i.e., the quartiles of smaller and larger cities and of municipalities with the highest and lowest GDP per capita because we believe these divisions are relevant to this analysis.

Table 18 - Calculations of fixed effects using hospitalizations by age per thousand live births as the dependent variable

	Dependent Variable		
	hop_until1_n	hop1_4_n	hop5_9_n
water_service	0.077*	0.035	-0.020
	(0.040)	(0.057)	(0.051)
sewage_conection	-0.020	-0.017	-0.039
	(0.020)	(0.027)	(0.029)
sewage_treatment	-0.011	-0.003	-0.019
	(0.014)	(0.020)	(0.022)
loss rate	-0.033	-0.111*	-0.042
	(0.044)	(0.057)	(0.052)
nonstantard turbidity rate	0.051*	-0.001	-0.058
	(0.030)	(0.075)	(0.054)
nonstantard turbidity rate	-0.012	0.038	0.051
	(0.030)	(0.036)	(0.037)
nonstantard total coliform rate	0.010	0.032	-0.066
	(0.102)	(0.173)	(0.105)
population	YES	YES	YES
% PSF	YES	YES	YES
GPD per capita	YES	YES	YES
vacination coverage	YES	YES	YES
educ up tp 4 years	YES	YES	YES
year dummies	YES	YES	YES
observations	1,668	1,668	1,668
R2	0.021	0.039	0.057

Obs: *** p<.01, ** p<.05, * p<.1

Source: Authors' elaboration

Table 19 - Calculations of fixed effects using hospitalizations for each disease per hundred thousand inhabitants as the dependent variable from 2005 to 2008 (semi-balanced sample)

	Dependent Variable							
	hop_dys_inh	hop_pol_inh	hop_hep_inh	hop_chol_inh	hop_tub_inh	hop_tet_inh	hop_diph_inh	hop_diar_inh
water_service	-0.0141**	-0.0000	-0.0004	0.0000	0.0000	0.0000	-0.0000*	0.0073
	(0.0059)	(0.0001)	(0.0003)	(0.0000)	(0.0005)	(0.0000)	(0.0000)	(0.0051)
sewage_conection	0.0004	-0.0000	-0.0003	-0.0000	0.0005	-0.0000	-0.0000	-0.0007
	(0.0031)	(0.0000)	(0.0002)	(0.0000)	(0.0006)	(0.0000)	(0.0000)	(0.0031)
sewage_treatment	-0.0002	-0.0000	-0.0002	0.0000	0.0002	-0.0000	0.0000	-0.0026
	(0.0023)	(0.0000)	(0.0002)	(0.0000)	(0.0004)	(0.0000)	(0.0000)	(0.0026)
loss rate	-0.0069	-0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0023
	(0.0056)	(0.0001)	(0.0004)	(0.0000)	(0.0005)	(0.0000)	(0.0000)	(0.0049)
nonstantard turbidity	-0.0123	0.0000	0.0003	0.0000	-0.0006	0.0000	-0.0000*	0.0084
rate	(0.0089)	(0.0000)	(0.0002)	(0.0000)	(0.0004)	(0.0000)	(0.0000)	(0.0053)
nonstantard turbidity	-0.0019	-0.0000	0.000**	0.0000	0.0003	-0.0000	0.0000	0.0025
rate	(0.0059)	(0.0000)	(0.0002)	(0.0000)	(0.0003)	(0.0000)	(0.0000)	(0.0029)
nonstantard total	0.0226*	-0.0002	-0.0018**	-0.0000	-0.0029*	0.0000	0.0000	-0.0119
coliform rate	(0.0133)	(0.0002)	(0.0009)	(0.0000)	(0.0017)	(0.0001)	(0.0001)	(0.0120)
population	YES	YES	YES	YES	YES	YES	YES	YES
% PSF	YES	YES	YES	YES	YES	YES	YES	YES
GPD per capita	YES	YES	YES	YES	YES	YES	YES	YES
vacination coverage	YES	YES	YES	YES	YES	YES	YES	YES
educ up tp 4 years	YES	YES	YES	YES	YES	YES	YES	YES
year dummies	YES	YES	YES	YES	YES	YES	YES	YES
observations	1,668	1,668	1,668	1,668	1,668	1,668	1,668	1,668
R2	0.402	0.042	0.026	0.006	0.008	0.005	0.143	0.096

Obs: *** p<.01, ** p<.05, * p<.1

These calculations also include the period from 2005 to 2008 and cover the semi-balanced sample. Thus, Tables 20 and 21 show the model constrained by municipalities with populations of less than 12,500 inhabitants and with populations of over 80,000 inhabitants, respectively. With regard to the smaller municipalities, an expected and significant impact was found only for access to water on hospitalization for dysentery and for water quality on hospitalization (residual chlorine) and infant mortality (fecal coliforms); other significant results were unexpected. For the larger municipalities, the influence of sanitation indicators on the hospitalization of children can be noted. The tendency towards universalization of water access in large urban centers can explain this result, whereas sewage collection and treatment remain incipient, and their expansion therefore tends to have a greater impact on hospitalization data.

With regard to city incomes, Table 22 includes calculations only for municipalities that have a GDP per capita of less than R$ 5000, in which sewage treatment has a great impact on the reduction of both mortality and morbidity indicators. In the poorest municipalities, there is a tendency of low levels of sanitation and of greater scope for reducing diseases and deaths.

Table 23 evaluates data from municipalities with per capita GDP over R$ 11,000. Again, the impact of sanitation levels on the hospitalization of children and on general cases of polio and hepatitis can be observed in addition to a significant effect of water treatment on a reduction in dysentery hospitalizations. However, most coefficients have low economic and statistical significance; thus, no robust effect of sanitation can be demonstrated, which again can be explained by the decrease in the expansion of sanitation in recent years compared with previous decades.

Table 20 - Calculations of fixed effects only for municipalities with fewer than 12,500 inhabitants from 2005 to 2008 (semi-balanced sample)

	Dependent Variable														
	dea_ate1_n	dea_1a12_n	dea1_4_n	dea5_9_n	hop_until1_n	hop1_4_n	hop5_9_n	hop_dys_inh	hop_pol_inh	hop_hep_inh	hop_chol_inh	hop_tub_inh	hop_tet_inh	hop_diph_inh	hop_diar_inh
water_service	0.168	0.094	0.066	0.117	-0.039	0.474	-0.097	-0.038***	-0.001	-0.000	-	0.003**	0.000	-	0.034
	(0.205)	(0.074)	(0.059)	(0.123)	(0.205)	(0.330)	(0.287)	(0.014)	(0.001)	(0.002)	-	(0.002)	(0.000)	-	(0.025)
sewage_conection	0.280	0.092	0.263***	0.177**	-0.039	0.018	-0.670**	-0.016	0.001	-0.000	-	-0.004	0.000	-	0.025
	(0.195)	(0.174)	(0.098)	(0.071)	(0.217)	(0.318)	(0.269)	(0.011)	(0.001)	(0.001)	-	(0.003)	(0.000)	-	(0.026)
sewage_treatment	0.024	0.054	-0.032	0.018	0.121	-0.013	-0.097	0.002	0.000	-0.000	-	-0.000	-0.000	-	0.010
	(0.112)	(0.043)	(0.021)	(0.034)	(0.096)	(0.095)	(0.108)	(0.008)	(0.000)	(0.001)	-	(0.001)	(0.000)	-	(0.010)
loss rate	-0.191	-0.044	0.101**	-0.152	0.298	-0.269	0.002	0.015	0.000	-0.001	-	-0.000	-0.000	-	0.010
	(0.180)	(0.114)	(0.045)	(0.109)	(0.271)	(0.236)	(0.278)	(0.015)	(0.000)	(0.002)	-	(0.002)	(0.000)	-	(0.020)
nonstantard turbidity rate	-0.954	-1.160	-0.964***	0.427	3.076*	0.840	-0.743	-0.063	0.001	0.010	-	-0.001	0.000	-	0.203
	(1.492)	(0.722)	(0.372)	(0.468)	(1.690)	(3.427)	(1.225)	(0.175)	(0.001)	(0.011)	-	(0.009)	(0.000)	-	(0.161)
nonstantard turbidity rate	0.251	0.268***	-0.014	-0.059	-0.215	0.014	0.108	0.013	-0.000	-0.001	-	0.000	0.000	-	-0.025*
	(0.167)	(0.086)	(0.037)	(0.051)	(0.146)	(0.293)	(0.199)	(0.014)	(0.000)	(0.001)	-	(0.001)	(0.000)	-	(0.015)
nonstantard total coliform rate	2.814**	0.797	0.196	0.141	0.490	-0.903	0.667	0.093	-0.001	0.000	-	-0.001	0.001	-	-0.173*
	(1.293)	(0.669)	(0.277)	(0.352)	(1.165)	(2.167)	(1.156)	(0.076)	(0.002)	(0.007)	-	(0.010)	(0.001)	-	(0.097)
population	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
% PSF	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
GPD per capita	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
vacination coverage	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
educ up tp 4 years	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
year dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
observations	191	191	191	191	191	191	191	191	191	191	191	191	191	191	191
R2	0.121	0.134	0.278	0.212	0.077	0.129	0.066	0.115	0.141	0.043	.	0.080	0.093	.	0.044

Obs: *** p<.01, ** p<.05, * p<.1

Source: Authors' elaboration

Table 21 - Calculation of fixed effects only for municipalities with more than 80 000 inhabitants from 2005 to 2008 (semi-balanced sample)

	Dependent Variable														
	dea_ate1_n	dea_1a12_n	dea1_4_n	dea5_9_n	hop_until1_n	hop1_4_n	hop5_9_n	hop_dys_inh	hop_pol_inh	hop_hep_inh	hop_chol_inh	hop_tub_inh	hop_tet_inh	hop_diph_inh	hop_diar_inh
water_service	-0.008	0.003	-0.012	0.001	-0.026	0.015	0.056	-0.004	0.000	-0.000	0.000	0.001	-0.000	-0.000	-0.007*
	(0.024)	(0.012)	(0.009)	(0.006)	(0.032)	(0.044)	(0.043)	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)
sewage_conection	-0.006	-0.001	-0.004	-0.002	-0.039**	-0.034	-0.025	0.005	-0.000	-0.000	0.000	-0.001	-0.000	-0.000	0.001
	(0.010)	(0.005)	(0.004)	(0.003)	(0.020)	(0.024)	(0.020)	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)
sewage_treatment	0.014**	0.002	-0.001	-0.002	-0.023	-0.022	-0.029**	-0.005*	-0.000	-0.000	0.000	-0.000	0.000	0.000	0.000
	(0.007)	(0.005)	(0.002)	(0.002)	(0.018)	(0.024)	(0.013)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
loss rate	-0.038**	-0.026*	0.003	0.016***	-0.094**	-0.118**	-0.068**	-0.008*	-0.000	0.000	0.000*	-0.000	0.000	-0.000	-0.007
	(0.019)	(0.014)	(0.007)	(0.006)	(0.043)	(0.050)	(0.032)	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)
nonstantard turbidity rate	-0.008	-0.003	-0.013***	0.003	0.031	0.103**	0.041	-0.006	0.000	0.000	0.000	-0.000	0.000	-0.000	0.005
	(0.019)	(0.008)	(0.004)	(0.003)	(0.040)	(0.045)	(0.032)	(0.004)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.007)
nonstantard turbidity rate	-0.009	-0.016*	-0.004	-0.010***	0.043	0.065*	0.039	0.007*	-0.000**	0.001**	-0.000	0.000	0.000	-0.000	0.001
	(0.015)	(0.009)	(0.007)	(0.004)	(0.030)	(0.038)	(0.039)	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)
nonstantard total coliform rate	0.011	0.027	0.003	0.000	-0.093	-0.147*	-0.050	0.015**	-0.000	-0.000	-0.000	-0.001	0.000	-0.000	-0.013
	(0.033)	(0.017)	(0.011)	(0.008)	(0.060)	(0.083)	(0.069)	(0.007)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.011)
population	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
% PSF	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
GPD per capita	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
vacination coverage	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
educ up tp 4 years	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
year dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
observations	699	699	699	699	699	699	699	699	699	699	699	699	699	699	699
R2	0.081	0.059	0.041	0.037	0.071	0.104	0.151	0.147	0.081	0.107	0.035	0.065	0.036	0.021	0.050

Obs: *** p<.01, ** p<.05, * p<.1

Source: Authors' elaboration

Table 22 - Calculation of fixed effects only for municipalities with GDP per capita less than R$ 5,000 from 2005 to 2008 (semi-balanced sample)

	Dependent Variable														
	dea_ate1_n	dea_1a12_n	dea1_4_n	dea5_9_n	hop_until1_n	hop1_4_n	hop5_9_n	hop_dys_inh	hop_pol_inh	hop_hep_inh	hop_chol_inh	hop_tub_inh	hop_tet_inh	hop_diph_inh	hop_diar_inh
water_service	0.047	-0.017	0.005	0.016	-0.086	0.148	0.193	-0.008	0.000	0.000	0.000	0.002**	-0.000	-0.000	0.016
	(0.093)	(0.047)	(0.027)	(0.034)	(0.108)	(0.229)	(0.165)	(0.020)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.021)
sewage_conection	0.048	-0.063	0.028	-0.015	-0.173	0.029	0.000	0.007	0.000	-0.000	0.000	0.001	0.000**	-0.000	0.003
	(0.080)	(0.055)	(0.029)	(0.033)	(0.126)	(0.209)	(0.090)	(0.019)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.015)
sewage_treatment	-0.057*	-0.075***	-0.027**	0.008	-0.146	-0.196	-0.137**	-0.011	0.000	-0.001***	0.000	-0.000	0.000*	0.000	-0.014**
	(0.035)	(0.018)	(0.012)	(0.016)	(0.090)	(0.119)	(0.055)	(0.011)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.006)
loss rate	0.033	0.046	0.014	0.029	0.201	-0.132	0.069	-0.044**	-0.000*	0.001	-0.000	0.000	-0.000**	0.000	0.015
	(0.095)	(0.072)	(0.036)	(0.039)	(0.140)	(0.198)	(0.129)	(0.021)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.022)
nonstantard	-0.084	-0.073***	0.019	-0.003	-0.003	-0.132	-0.173	-0.022	0.000	0.001	-0.000	-0.001*	0.000	-0.000	0.020*
turbidity rate	(0.059)	(0.022)	(0.020)	(0.019)	(0.059)	(0.151)	(0.112)	(0.019)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.012)
nonstantard	0.036	0.026	-0.075**	0.003	0.032	0.049	0.057	0.001	0.000	-0.000	-0.000	0.001*	-0.000	-0.000	-0.005
turbidity rate	(0.064)	(0.056)	(0.030)	(0.010)	(0.030)	(0.051)	(0.103)	(0.006)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.008)
nonstantard total	0.678*	-0.146	-0.053	-0.006	-0.504	0.789	0.644	0.066	-0.000	-0.001	-0.000	-0.000	0.000	-0.000	-0.066
coliform rate	(0.367)	(0.133)	(0.108)	(0.147)	(0.366)	(0.523)	(0.403)	(0.057)	(0.000)	(0.002)	(0.000)	(0.004)	(0.000)	(0.000)	(0.073)
population	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
% PSF	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
GPD per capita	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
vacination coverage	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
educ up tp 4 years	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
year dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
observations	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
R2	0.424	0.350	0.391	0.266	0.414	0.365	0.372	0.265	0.269	0.356	0.139	0.369	0.429	0.188	0.191

Obs: *** p<.01, ** p<.05, * p<.1

Source: Author's Elaboration

Table 23 - Calculation of fixed effects only for municipalities with GDP per capita greater than R$ 11,000 from 2005 to 2008 (semi-balanced sample)

	Dependent Variable														
	dea_ate1_n	dea_1a12_n	dea1_4_n	dea5_9_n	hop_until1_n	hop1_4_n	hop5_9_n	hop_dys_inh	hop_pol_inh	hop_hep_inh	hop_chol_inh	hop_tub_inh	hop_tet_inh	hop_diph_inh	hop_diar_inh
water_service	-0.014	0.010	0.010	-0.028	0.038	0.015	0.015	-0.022**	-0.000	0.000	0.000	-0.000	0.000	-0.000	0.014
	(0.051)	(0.035)	(0.018)	(0.024)	(0.084)	(0.090)	(0.111)	(0.010)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.010)
sewage_conection	0.023	0.008	0.005	0.011	-0.051	-0.021	-0.062*	-0.006	-0.000*	-0.000**	0.000	-0.000	-0.000	-0.000	0.003
	(0.023)	(0.015)	(0.007)	(0.007)	(0.032)	(0.036)	(0.035)	(0.004)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.004)
sewage_treatment	0.026**	0.010	-0.002	-0.002	-0.008	-0.039	-0.077***	-0.000	-0.000*	-0.000	0.000	-0.000	-0.000	0.000	0.002
	(0.013)	(0.008)	(0.005)	(0.004)	(0.020)	(0.026)	(0.026)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)
loss rate	-0.012	0.020	0.005	0.000	-0.010	-0.169***	-0.092	0.000	-0.000	0.001	0.000	-0.000	0.000	0.000	-0.008
	(0.056)	(0.038)	(0.014)	(0.015)	(0.059)	(0.065)	(0.087)	(0.007)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.010)
nonstantard turbidity rate	-0.250***	-0.126***	-0.031	-0.057	0.182	0.139	0.018	-0.024	0.001	-0.001	-0.000	0.001	-0.000	0.000	0.006
	(0.088)	(0.045)	(0.027)	(0.047)	(0.133)	(0.171)	(0.253)	(0.018)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.015)
nonstantard turbidity rate	-0.001	-0.019	0.004	0.009	0.005	-0.025	0.037	0.001	-0.000	-0.000	0.000	0.000	-0.000	0.000	0.007
	(0.045)	(0.023)	(0.013)	(0.012)	(0.051)	(0.054)	(0.051)	(0.006)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.008)
nonstantard total coliform rate	0.268	0.033	0.140**	0.108*	-0.074	-0.062	-0.224	-0.004	-0.001	-0.003	-0.000	-0.004	0.000	-0.000	-0.029
	(0.232)	(0.106)	(0.062)	(0.062)	(0.192)	(0.563)	(0.342)	(0.028)	(0.001)	(0.002)	(0.000)	(0.003)	(0.000)	(0.000)	(0.026)
population	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
% PSF	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
GPD per capita	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
vacination coverage	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
educ up tp 4 years	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
year dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
observations	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779
R2	0.067	0.032	0.046	0.046	0.060	0.052	0.060	0.600	0.049	0.064	0.064	0.035	0.022	0.319	0.092

Obs: *** p<.01, ** p<.05, * p<.1

Source: Authors' elaboration

4.3. Cost-benefit Analysis

In this section, we evaluate the cost of investments in sanitation during the 2000s to implement public policies. For this purpose, the Brazilian Finances (FINBRA) database, which contains accounting data for states and municipalities in the country, was used. This database has data on revenue and expenses distinguished by activity and function. The cities' ratio of spending on sanitation from 2003 to 2008 can thus be ascertained. This relationship is divided into spending on rural and urban sanitation from 2004 on.

This analysis assumes the impact of investment in sanitation if all the expenditure were allocated for the improvement of sanitation, which, according to the results, was the group that showed a statistically significant impact on the reduction of the hospitalization of children. For this group, the change in the sewage collection rate in municipalities between 2003 and 2008 was evaluated. In parallel, the total expenditures for sanitation during this period were calculated to obtain the per-capita cost of increasing by 1% the sewage collection in this period in every city that has complete data for this sanitation indicator in these years, totaling 309 municipalities. Spending on basic sanitation per capita in Brazil was calculated using the expenditures at the municipal level weighted by the population of these municipalities in 2008.

We found that for a 1% increase in the sewage collection rate in the country, investments of R$ 191.31 per capita in the period, or R$ 31.88 per year, were required. Given the coefficient of sewage collection on hospitalizations of children under one year of age (-0.248) found in Table 21, (additional) expenses of R$ 19.14 per capita on sanitation were required annually to achieve a reduction of 1% in cases of infant morbidity. It is worth reiterating that we are overestimating the costs of sanitation (the variable considered covers the costs of both water and sewage treatment). This value, however, reflects the situation of greater political inefficiency for sanitation.

Is this cost high? To answer this question, the amount of government spending on sanitation should be noted. For the municipalities evaluated, we see that the average per capita investment in terms of the introduction of sanitation was R$ 1,293.64 between 2003 and 2008, generating an annual expenditure of R$ 215.60 per citizen. However, the bias of the unbalanced panel also affects this cost-benefit analysis because municipalities that have complete sanitation data also tend to have increased investment in the sector. The expenditures cited for a decrease of 1% in child hospitalizations may therefore be overestimated. If we consider all Brazilian municipalities, the average

expenditure per citizen in sanitation drops to only R$ 39, i.e., if we increase spending on sanitation by 50% (R$ 19.14), morbidity can be decreased by 1%. Additionally, note that of the investments in sanitation, approximately 72% were focused in urban areas, whereas 2% were applied to rural areas, and the rest had no specific destination.

According to FINBRA, government spending on healthcare in Brazil was R$ 304.08 per capita in 2008. Of this amount, R$ 121.18 and R$ 114.21 per person were spent on primary care and hospital care, respectively. These classifications do not have divisions, however, and thus preclude the comparison of investment efficiency, although spending on sewage collection for the reduction of childhood diseases seems high when compared with spending on healthcare. One reason for this result may be observed in the production inefficiency indices, which indicate that the cost of sanitation in Brazil is high due to high wastage systems or high initial costs (sunk cost) in the sector. In addition, this result might indicate that the cost of sanitation in the country is high because of taxes and lack of infrastructure. To verify the effectiveness of this investment, we should compare it with other public actions that can reduce cases of illnesses and deaths among children, such as those indicated by physical data from hospitals.

5. Conclusions

The present study seeks to identify possible effects of the expansion of sanitation on health indicators related to mortality and morbidity in children in Brazil. Using a recent database covering various annual sanitation levels in Brazilian municipalities, we identified the need to differentiate existing sanitation channels. The variables of access to piped water, indicators of access to the sewerage system, assessments of the quality of water consumed, and rates of the production efficiency of water all produced different results on the population’s health. It is also necessary to distinguish the effects that sanitation may cause. The impact on infant mortality, the most observed variable in the present study, may differ from the effect on hospitalizations or on specific diseases caused by any of these variables.

The bias caused by unbalanced panel data reinforces the need for careful study of the database in the evaluation of public policies. When different non-constructed observation units are addressed, as in the case of the municipalities, the likelihood of some type of random imbalance increases. The incorporation of all Brazilian

municipalities in the SNIS database in future years will facilitate future evaluations of the implications of basic sanitation in the country and will leverage the importance of this sector for the welfare of citizens.

Our results indicate that for the sample as a whole, a 1% reduction in the incidence of nonstandard total coliform leads to a decline of 0.12 deaths of children under one year of age, including the neonatal period, for every thousand live births. With regard to hospitalizations due to disease, only the improvement of access to water and the reduction of total coliforms appear to reduce the rate of hospitalization for dysentery (for access to water) and hepatitis and tuberculosis (for reduction in total coliforms). Access to treatment and sewage collection appears to reduce the mortality of children up to four years of age and the hospitalization of children aged five to nine years of age in poor municipalities. Finally, access to water and sewerage appear to reduce hospitalizations for dysentery and hepatitis in municipalities with incomes above the median in Brazil.

In terms of public policy, it is worth noting that even if access to/treatment of water reaches levels of approximately 80%, the lack of access and treatment still influences the incidence of diseases such as dysentery. Conversely, the policy of collecting and treating sewage has lower access levels (approximately 50%) and has more devastating consequences (deaths in the poorest cities) in the absence of such services. There is also low efficiency of water and sanitation production because the wastewater rate reaches more than 50% in many regions. These two items (sewage and losses) must improve to promote advances in child health through the effect of sewage provision on hospitalizations and through the possible indirect effect of reducing water wastage on other sanitation indicators.

Finally, it is reasonable to state that because we worked with different samples and weightings due to unbalanced data, most of our calculations were unable to demonstrate a strong effect of sanitation policies on health indicators.

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