



The Review of Regional Studies

The Official Journal of the Southern Regional Science Association



Waterborne Diseases, Basic Sanitation, and Health: Perspectives for Brazil's Legal Amazon*

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Abstract: Access to sanitation services is a basic human right, although a large part of the Brazilian population has limited access to such services. This paper investigates the relationship between access to sanitation services and the health conditions of the population in one of Brazil's regions with the lowest infrastructure levels: the Legal Amazon. Using a dynamic panel model, the study analyzes how access to treated water impacts hospital admissions due to waterborne diseases. The results show that access to treated water reduces such admissions, thereby indicating a need to implement public policies in the fields of both sanitation and health. Our findings suggest that a program should be established to promote basic sanitation for the Legal Amazon with incentives for the private sector to participate, such as subsidies for companies to operate in the region. In addition, a data collection system must be designed to make it feasible to undertake studies aimed at drafting public policies which enable long-term planning.

Keywords: basic sanitation, the Legal Amazon, dynamic panel, economic development

JEL Codes: I12, I19, O18

1. INTRODUCTION

Basic sanitation, a human right laid down by the United Nations (UN), was formalized as a legal right within Brazil by its 1988 Constitution. The law of National Guidelines for Basic Sanitation (LDB - Law 11,445/2007) defined this right as the provision of services and infrastructure for the supply of treated water; sewage networks; street cleaning and solid waste management; and, the drainage and management of urban rainwater. In addition to being an aspect of basic infrastructure, sanitation is also important because of its relationship to and interdependence with public health, environmental preservation, and the economy.

In Brazil, the precariousness of the sanitation system, dearth of investment, and inequality between the regions underline the importance of studies on the theme. In fact, according

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to the Brazilian Institute of Geography and Statistics (IBGE) for 2017, only 38.2 percent of municipalities had a municipal policy for sanitation, collection, and disposal of waste (Marques et al., 2012). Brazilian regional disparities lead to enormous variation in sanitation infrastructure across the country. Historically, the country's sanitation expansion has been extremely heterogeneous and, as a consequence, the Center-South has a much more highly developed infrastructure than the Northern or Northeastern regions (Teixeira, 2011). In the Northern region, only 10.45 percent of the population have access to sewage services. While 35 million Brazilians do not have access to treated water, the Northern region once again presents the lowest percentage access of only 57.49 percent of the population.

Concern about the provision of basic sanitation is justified because of its close relationship with health conditions. A study by the World Health Organization showed that each dollar invested in sanitation results in 4 dollars of savings in health costs worldwide (World Health Organization, 2014). This result is due to the fact that certain diseases are directly related to the lack of sanitation, those cataloged as waterborne diseases.¹ In Brazil, statistics show that in 2017, the Unified Health System's (SUS) hospital admissions related to diseases caused by lack of sanitation and access to quality water generated costs of one hundred million reais. In addition, Silva (2008) showed that waterborne diseases were responsible for 65 percent of hospital admissions of children up to 10 years of age and for 80 percent of all illnesses in developing countries. Given this perspective and considering Brazilian regional inequalities, the present study analyzes the effect of access to treated water on hospital admissions due to waterborne illnesses, a proxy for health conditions, in the Legal Amazon region from 2010 to 2017.

Almost all of the Legal Amazon lies within the country's Northern region, considered the least developed in terms of access to basic sanitation. The region is made up of the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, Tocantins, and Maranhão. The Legal Amazon is characterized by its complexity and diversity, covers 61 percent of the national territory, and has 12.5 percent of the population. In addition, according to Viana (2014), the debate about the Legal Amazon focuses on issues involving deforestation, burning, impacts of hydroelectric dams, and neglects essential aspects such as health and improving the basic sanitation infrastructure. Although the region has great potential in terms of water, it has the worst rates of water supply.

To conduct the analysis, this study uses a dynamic panel proposed by Arellano and Bond (1991). This methodology is preferred due to the dynamic relationships between variables and the ability to control for endogeneity. The GMM System was used as an estimator, with a lag of the dependent variable as an instrumental variable. The endogenous variable is access to treated water in municipalities in the Legal Amazon. The data used for the analysis were provided by the Ministry of Health through the SUS hospital information system (DATASUS), the National Sanitation System (SNIS), and the Brazilian Institute of Geography and Statistics (IBGE) from 2010 to 2017.

The results indicate that access to quality treated water, or lack thereof, has a major impact on health conditions. These findings suggest that it is essential for people to have

¹According to the Oswaldo Cruz Institute (FIOCRUZ), these diseases are: amebiasis, cholera, dengue, acute diarrheal diseases, schistosomiasis, filariasis, typhoid, giardiasis, hepatitis A, and leptospirosis. All can be contracted by ingestion and/or contact with contaminated water.

access to treated water. Furthermore, this water must meet a minimum level of quality in order to reduce the chances of contamination by waterborne diseases.

Although this issue has been studied previously in Brazil, this paper contributes to the literature by analyzing a Brazilian region which is varied and vital for the environmental balance of the planet, but is not as well studied. In addition, the econometric approach, has not been used previously to study this issue in Brazil. The GMM System estimator allows researchers to control for the endogenous relationship between sanitation and health conditions.

2. THEORETICAL AND EMPIRICAL ASPECTS OF THE RELATIONSHIP BETWEEN SANITATION AND HEALTH

According to Heller (1998), the relationship between sanitation and economic development is clear and direct, as more developed countries provide greater sanitation coverage and, consequently, have healthier populations. It is clear that this relationship was consolidated through health conditions, which were established as an essential element in the process of economic growth from the advent of the theory of human capital onwards. In that sense, Schultz (1961) defends the pre-eminence of investments in human capital, that is, in people's skills and capacities, which is particularly enhanced through improvements in education and health conditions. This whole discussion has defined the input of health as fundamental to the process of economic growth and sustainability in developing countries (Ramalho et al., 2008).

In light of this theoretical evolution, the debate on the dearth of sanitation has been gaining international prominence since the 1980s. The importance has been particularly evident in developing countries, where health conditions, especially for children, are extremely precarious, given the history of low levels of public investment in infrastructure and the high incidence of diseases related to lack of water and excreta treatment (Barreto, 1997; Leivas et al., 2015)

The literature points out that the relationship between sanitation and health conditions is multifaceted, involving various aspects of a technological, institutional, behavioral, cultural, socioeconomic, familiar, environmental, financial, and governmental nature. Studies have analyzed this relationship, denoting a variety of actions in sanitation and in different socioeconomic regions while using different methods. Analyses associating water supply and sewage with health conditions stand out, like that of this study. A scarcity of basic sanitation generates an unhealthy environment conducive to the spread of disease. In addition, untreated water can contain various pathogens harmful to health, which are orally transmitted to humans through the ingestion of contaminated food and water and through contact with the skin (Barreto, 1997; Roberts, 1997).

In general, the above-mentioned studies use the incidence of diarrhea, infant mortality, life expectancy, etc. as health indicators (Heller, 1998). In addition, they analyze aspects of the effects of poor sanitation on health in both the short and long term. The literature shows that the long-term effects are more serious in that they generate negative externalities (Barreto, 1997).

Many of these studies concentrate on developing countries, given their relative precariousness in terms of access to basic sanitation. For example, Bhalotra et al. (2017) showed that in Mexico improvements in the quality of the water supply contributed to a 50 percent reduction in infant mortality caused by diarrheal diseases. In Nepal, Coffey et al. (2018) related the incidence of anemia in children from different regions with precarious sanitary conditions over the 2006-2011 period using panel data which presented a positive relationship.

Several studies examining India have shown that there is a positive relationship between sanitation and health conditions. For example, Andres et al. (2017) related access to the sanitation network with child health, when attempting to verify the externalities of these improvements. Augsburg and Rodriguez-Lesmes (2018) analyzed the effect of improved sanitation coverage on health conditions, using children's height-for-age as an indicator for health of the country. Duflo et al. (2015) tested the aforementioned relationship for rural communities in the country and found that there was a 30 to 50 percent decrease in severe cases of diarrhea with improved sanitation.

Other studies have analyzed the relationship between access to sanitation services and health conditions in Brazil. Soares (2007) analyzed these conditions and the evolution of well-being in Brazilian municipalities, using data for the 1970-2000 period. While increased incomes were key issues in enhancing well-being, education and sanitation were also crucial elements in increasing life expectancy. Leivas et al. (2015) used microdata and macrodata to study the same relationship. Using macrodata, they estimated a model with static panel data, with fixed effects, and a dynamic panel, for the 2001-2010 period, and found that increased sanitation service coverage reduced infant mortality. Using microdata from the National Household Sample Survey (2008), they used a probit binomial model and found that, on an individual basis, access to the water network did not impact children's health. However, in terms of access to the sewage network, the result was different: where there is an adequate sewage system, children tend to enjoy better health. In the specific context of the relationship between waterborne diseases and sanitation, Mendonça and Motta (2005) analyzed infant mortality due to the incidence of these diseases. They concluded that improved sanitation services explain part of the reduction in infant mortality stemming from these diseases. They also concluded that investments and expenditure on water treatment are more justifiable than those related to health services. Along the same lines, Uhr et al. (2016) conducted a study which related access to sanitation with cases of hospital admissions caused by waterborne diseases using a panel data model. They concluded that access to garbage and sewage collection services contributes to reducing the number of hospital admissions, but access to treated water was insignificant. They raised the hypothesis that the vast majority of Brazilian society already has access to treated water.

3. METHODS

3.1. Specifying the Econometric Model

A panel data method was used to analyze the relationship between sanitation and health conditions. In general, there are certain advantages attached to this approach, including: control of heterogeneity between cross-sectional units; more informative data with greater

variability and less collinearity between variables; more degrees of freedom; greater efficiency; and the possibility of studying the dynamic relationship between variables. However, there are also some disadvantages: problems inherent to cross-sectional data (heteroscedasticity); autocorrelated and cross-correlated time series; and simultaneity and endogeneity (Johnston and Dinardo, 1997; Marques, 2000). Because of the special characteristics of panel data, models with suitable application need to be considered. These include traditional models for static panels, such as Pooled, Fixed Effects and Random Effects; and dynamic models, such as that used in this study, based on the method developed by Arellano and Bond (1991).

The dynamic panel has two advantages. The first is the possibility of inserting the lagged dependent variable into the model, which facilitates understanding of the dynamic relationships. The second is the control for endogeneity which, as mentioned above, is very common in this type of estimation. Endogeneity can occur when there is a correlation between the dependent variable and the explanatory variables, or it could be the result of correlation between one of the lagged regressors and the error term μ_{it} , via α_i , thereby making the Ordinary Least Square (OLS) estimators biased and inconsistent. The study undertaken by Arellano and Bond (1991) and enhanced by Arellano and Bover (1995), known as System GMM, controls for endogeneity by using instruments in level for the first-difference equation and first-difference instruments for the level equation (Marques, 2000).

This study uses the System GMM estimator with one lag of the dependent variable, using the variable which denotes access to treated water in municipalities in the Legal Amazon region as an instrument or endogenous variable. This instrument is justified because health and sanitary conditions could be related, as discussed in the previous section (Teixeira, 2011). The specification of the model to be estimated is:

$$\begin{aligned} HospitalAdm_{it} = & \alpha_j LagHospitalAdm_{i,t-j} + \beta_1 WaterIndex_{it} + \beta_2 Quality_{it} \\ & + \beta_3 GDPpercapit_{it} + \beta_4 Livebirth_{it} + \beta_5 Acre_{it} + \beta_6 Amapa_{it} \\ & + \beta_7 Maranhao_{it} + \beta_8 Matogrosso_{it} + \beta_9 Roraima_{it} + \beta_{10} Rondonia_{it} \\ & + \beta_{11} Para_{it} + \beta_{12} Tocantins_{it} + \mu_{it} \end{aligned} \quad (1)$$

where i corresponds to the states belonging to the Legal Amazon and t corresponds to the year ($t = 2010, \dots, 2017$). *HospitalAdm* is the rate of admissions due to waterborne diseases per 100 thousand inhabitants; *LagHospitalAdm* is the dependent variable lagged by 1 period; *WaterIndex* corresponds to the percentage of people with access to treated water; *Quality* is an indicator of water quality, whose proxy is the percentage of non-standard chlorine samples; *GDPpercapita* is the log of GDP per capita; and *Livebirths* is the number of live births by municipality. *Acre*, *Amapa*, *Maranhao*, *Matogrosso*, *Roraima*, *Rondonia*, *Para*, and *Tocantins* are the indicator variables for states of the Legal Amazon region, with Amazonas as the omitted reference state. α_j and β_i are the parameters to be estimated and μ_{it} is the error term. As this is a dynamic panel, the error term decomposes according to equation (2):

$$\mu_{it} = \alpha_i + V_{it} \quad (2)$$

where α_i corresponds to the heterogeneity between states, that is, it has the specific char-

acteristics of state i that are invariant over time and can be correlated with covariates (*panel-level effects*). V_{it} corresponds to the term which varies independently over time/units (i.i.d) and is not correlated with the covariates.

First, the Durbin (1954), Wu (1974), and Hausman (1978) tests are performed to check for the existence of endogeneity. After this check, the model is estimated and tests are carried out afterwards to check the consistency of the estimates. For example, the Sargan test, which checks the adequacy and validity of the instruments used, is performed. The last test performed is the Arellano-Bond test for serial correlation, which verifies the autocorrelation between errors, in first and second orders.

3.2. Data Base and Variables

Table 1 below shows the variables used, selected according to the availability of data, whose sources are presented, and whose selection criteria were the studies cited therein. It should be noted that including water quality is justified by the fact that not only is it important to have access to treated water, but it is crucial that the water be at least minimally fit for consumption, according to studies by Mattos et al. (2019) and Teixeira (2011). In this case, the percentage of chlorine samples is used, as it has no correlation with the variable which denotes access to treated water.

With regards to the expected signs, it is anticipated that the relationship between access to treated water and GDP per capita to hospital admissions will be negative, which would indicate that improvement in these indicators reduces the rate of admissions due to waterborne diseases (Sousa and Leite Filho, 2008; Teixeira, 2011; Leivas et al., 2015). Based on the literature, there is no established relationship in terms of the variable which denotes water quality, as some studies show a positive and others a negative sign (Teixeira, 2011; Mattos et al., 2019). It is expected that the relationship between the variable which quantifies the number of children in municipalities of the Legal Amazon region and the dependent variable will be positive. According to Nascimento et al. (2013), children are more susceptible to contracting waterborne diseases, and 1 to 4 year-olds are most affected by diarrheal diseases.

Note that the Legal Amazon covers nine Brazilian states but, in the case of the state of Maranhão, not all municipalities are included in this region. Thus, only information referring to the Maranhão municipalities within the Legal Amazon according to IBGE data is used. The databases covering the 2010-2017 period were obtained from the Ministry of Health through the SUS hospital information system (DATASUS), the National Sanitation System (SNIS), and the Brazilian Institute of Geography and Statistics (IBGE).

4. RESULTS AND DISCUSSION

4.1. Descriptive Analysis

First, a descriptive analysis is undertaken to characterize the sample. Table 2 presents the statistics for the variables used in the model, considering a total of 1,104 observations corresponding to municipalities in the Legal Amazon, for which information was available for all the years analyzed. The average rate of hospital admissions caused by waterborne

Table 1: Variables Used in the Econometric Model

Variable	Description/definition	Authors	Source
DEPENDENT VARIABLE			
HospitalAdm	Admission rate for waterborne diseases* per 100 thousand inhabitants	Uhr, Schemechel and Uhr (2016)	DATASUS
EXPLANATORY VARIABLE			
LagHospitalAdm	Lagged variable of the rate of admissions for waterborne diseases per 100 thousand inhabitants	-	DATASUS
WaterIndex	Percentage of people with access to treated water	Mattos, Pinto and Teixeira (2019); Teixeira (2011)	SNIS
Quality	Quality water indicator, using the percentage of non-standard chlorine samples as a proxy	Mattos, Pinto and Teixeira (2019); Teixeira (2011)	SNIS
GDPpercapita	Logarithm of the municipal GDP per capita	Sousa and Leite Filho (2008); Leivas et al. (2015); Costa (2013)	IBGE
Livebirths	Number of live births per municipality	Benova et al. 2014	DATASUS
OTHER CONTROL VARIABLES			
Acre	dummy: 1 if the state is Acre and 0 otherwise	-	DATASUS/ IBGE/SNIS
Amapa	dummy: 1 if the state is Amapá, 0 otherwise		
Amazonas	dummy: 1 if the state is Amazonas, 0 otherwise		
Maranhao	dummy: 1 if the state is Maranhão, 0 otherwise		
Matogrosso	dummy: 1 if the state is Mato Grosso, 0 otherwise		
Roraima	dummy: 1 if the state is Roraima, 0 otherwise		
Rondonia	dummy: 1 if the state is Rondônia, 0 otherwise		
Para	dummy: 1 if the state is Pará, 0 otherwise		
Tocantins	dummy: 1 if the state is Tocantins, 0 otherwise		

Source: Drawn up by the authors.

Table 2: Descriptive Statistics of Sample

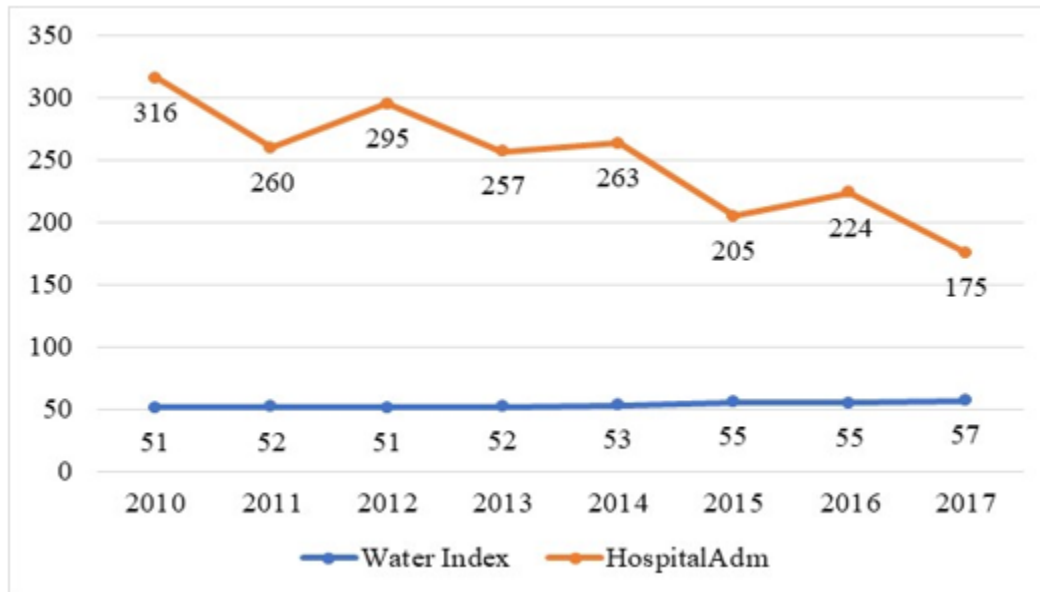
Variable	Mean	Std. Dev.	Min	Max
HospitalAdm	301.73	455.232	0	3,945.78
WaterIndex	57.02	28.702	0.05	100
Quality	9.77	26.40818	0	100
GDPpercapita	20,605.46	15,310.77	3,478.21	120,226.40
Livebirths	1,608.06	4312.36	47	42,809

Source: Drawn up by the authors.

diseases was 301.73 per 100 thousand inhabitants. With regards to the indicators of access to water, approximately 57.04 percent of the population had access to treated water, while for water quality 9.77 percent of the samples were non-standard.

Figure 1 presents the means of the variables for hospital admissions and the access to water index to show how they behaved over the years analyzed. For people with access to

Figure 1: Changes in Hospital Admission Rates for Waterborne Diseases per 100 Thousand Inhabitants and Percentage of People with Access to Water in the Legal Amazon Region from 2010 to 2017



Source: Author's calculations.

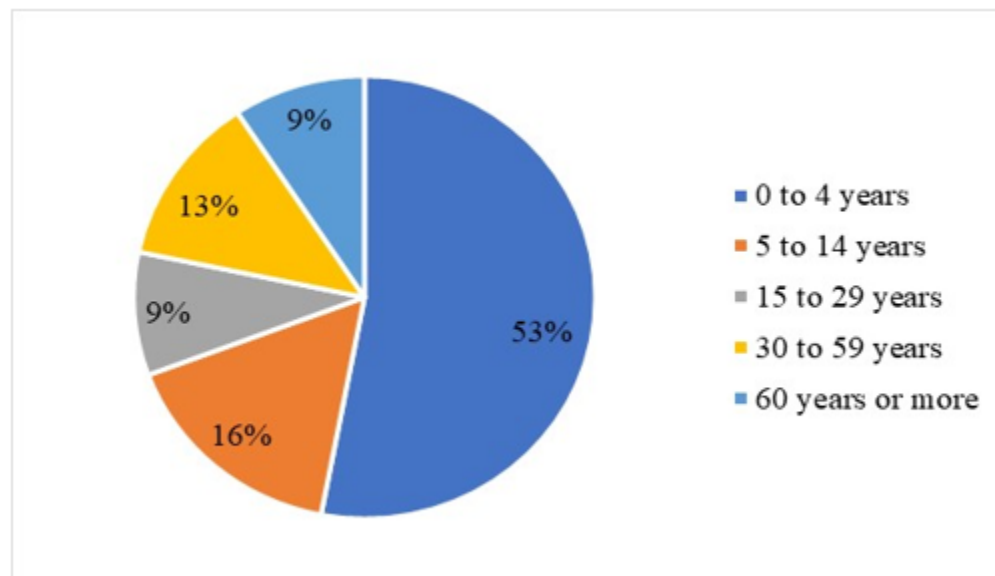
water, there is a slight upward tendency, which is maintained throughout the period, while the difference between 2010 and 2017 is approximately six percentage points.

In general, a decrease is seen in the rates of hospital admissions caused by waterborne diseases over the period analyzed. However, although there is a downward trend in hospital admissions, it fluctuates from year to year. This result is in line with Melo's 2014 study, in which he analyzes the overall picture of admissions due to diseases related to inadequate environmental sanitation (DRSAI) from 1996 to 2000. The results show that the states of the North and Northeast (which cover most of the Legal Amazon) present a much higher hospital admission frequency than that of other Brazilian regions. There were also great disparities between regions, with the incidence of diseases higher in places with no major investments in sanitation.

The literature discusses one other characteristic of waterborne diseases, namely the pre-eminence of children, which is also seen in Figure 2 where the percentage of hospital admissions due to these diseases per age group is shown. Marinho et al. (2016) corroborated these results in their analysis of a municipality in the state of Pará which found that the largest number of hospital admissions due to waterborne diseases, about 70 percent of cases, were of 0 to 5-year-olds, and the highest number of deaths was registered in 30 to 59-year-old adults.

Table 3, which aggregates the municipal data to the state level, presents the mean values for the period analyzed. In general, great disparities can be seen between certain states, such as Mato Grosso and Maranhão, which shows that there is great heterogeneity between the states which make up the Legal Amazon region. The state of Amazonas presents the

Figure 2: Percentage of Hospital Admissions for Waterborne Diseases, Based on Age Range in the Legal Amazon Region from 2010 to 2017



Source: Author's calculations.

Table 3: Mean of Variables Used per State in the Legal Amazon Region, 2010-2017

State	HospitalAdm	WaterIndex	GDPpercapita	Quality	Livebirths
Acre	183	51.90%	R\$ 14,614.00	10.67%	1,390.89
Amapa	113.15	28.97%	R\$ 18,792.31	23.33%	2,997.28
Amazonas	35.81	43.32%	R\$ 12,199.30	0.18%	5,855.61
Maranhao	606	39.98%	R\$ 9,102.77	27.07%	1,287.30
Matogrosso	183.66	82.85%	R\$ 38,131.34	2.17%	899.15
Roraima	218.62	61.05%	R\$ 17,580.26	18.80%	908.2
Rondonia	367.77	39.89%	R\$ 20,000.34	1.59%	945.94
Para	356.64	47.42%	R\$ 16,672.83	12.33%	3,916.38
Tocantins	167 83.06%	R\$ 22,474.51	0.20%	787.96	

Source: Drawn up by the authors.

lowest average rate of hospital admissions for waterborne diseases, while Maranhão presents the highest. In terms of the rate of supply of treated water to the population, the highest average for the period is seen in the state of Tocantins, followed by Mato Grosso, while the worst average is found in the state of Amapá, followed by Maranhão and Rondônia. Mato Grosso has the highest average GDP per capita, while Maranhão has the lowest. The worst index of average water quality was found in Maranhão, and in contrast, Amazonas had the best. Finally, in relation to the average number of live births, Amazonas presented the highest incidence while the lowest was seen in Tocantins.

The discrepancies in the region, especially with regards to access to treated water, where

there was a difference of 54.11 percentage points between states with the highest and lowest percentages, were also pointed out in a study undertaken by the NGO Trata Brasil (2018). This study analyzed the expansion of sanitary services in the country over the 2004-2016 period and showed that progress was made for thirteen years in relation to access to treated water. However, they argued that Brazil still has a long way to go to provide access to treated water for all its citizens. In terms of regional dynamics, the study highlighted the great concentration of investments. The Southern and Southeastern regions received the equivalent of 15 percent and 54 percent, respectively, of the total invested, while in contrast, the Northern region received only 3.8 percent of the total invested over the 2004-2016 period.

As mentioned above, the descriptive analysis showed great asymmetry between the states which make up the Legal Amazon in terms of the main indicators analyzed. In general, there was a tendency towards a decline in the rate of hospital admissions due to waterborne diseases and an increase in the rate of supply of treated water. However, causal relationship cannot be established yet, but will be discussed in the next subsection.

4.2. Econometric Results

Durbin's 1954 tests and that of Wu and Hausman (Wu, 1974; Hausman, 1978) showed endogeneity between the variables representing sanitation and health conditions. This endogenous relationship could be caused by the fact that investments in sanitation improve health conditions, but on the other hand, health indicators could be used as tools to determine investments in sanitation (Teixeira, 2011; Augsburg and Rodriguez-Lesmes, 2018). Thus, the model below treats the variable access to treated water as endogenous. As seen in Table 4, the Arellano and Bond test for serial correlation between errors is significant for first order errors and insignificant for those of second order. Thus, the model was specified correctly. Furthermore, the insignificance of the result of the Sargan Test shows that the instruments are valid.

The variable which shows access to treated water, the focus of this study, is statistically significant and has a negative relationship with the rate of hospital admissions. Thus, the higher the rate of access to treated water, the lower the rate of hospital admissions due to waterborne diseases. In this case, a 1 percent increase in access to treated water is associated with a 1.66 percent decline in the rate of hospital admissions. This finding confirms the importance of basic sanitation as a tool for improving health conditions, which in turn are an essential input in the process of economic growth. In addition, this result corroborates those found internationally by Duflo et al. (2015), Bhalotra et al. (2017), and Alsan and Goldin (2019). This result also confirms the findings of Leivas et al. (2015), who analyzed Brazil as a whole, and Sousa and Leite Filho (2008), who analyzed the Brazilian states of Bahia, Ceará, Maranhão, Piauí and Rio Grande do Norte.

Teixeira (2011) found similar results when analyzing Brazilian municipalities. He verified the relationship between access to basic sanitation and health conditions, in terms of morbidity and mortality. With regards to morbidity, he found that access to treated water has an impact on reducing hospital admissions. In terms of disease, he concluded that in cases of dysentery, a 5 percent increase in access to treated water decreases the number of cases by 1.2 percent for every 100 thousand inhabitants. In relation to mortality, the results

Table 4: Dynamic Panel Results of the Relationship between Sanitation and Health in the Legal Amazon Region, 2010-2017

Variable	Coeff.	Std. Err.	P> t
LagHospitalAdms	0.6568**	0.00254	0.000
WaterIndex	-1.6569**	0.08083	0.000
Quality	0.0745**	0.01823	0.000
GDPpercapita	-98.9316**	3.47708	0.000
Livebirths	0.0075**	0.00036	0.000
Acre	53.799**	12.7794	0.000
Amapa	-267.09**	18.4704	0.000
Maranhao	134.20**	10.2292	0.000
Matogrosso	231.94**	16.8404	0.000
Para	121.55**	9.66725	0.000
Rondonia	128.74**	11.8450	0.000
Roraima	160.92**	11.75432	0.000
Tocantins	255.57**	17.6097	0.000
Abond Test	1st. Order	-4.3231**	0.000
	2nd. Order	1.3106NS	0.1900
Sargan Test		128.255NS	0.8062

Notes: **Significant at 1 percent, *significant at 5 percent.

NS - not significant.

show that there is a decrease of 35 deaths per 1 million live births when access to treated water increases by 1 percent.

In another study conducted countrywide, Gamper-Rabindran et al. (2010) noted the significance of access to treated water. They analyzed all Brazilian municipalities and found that where there is less access to treated water, there is less effect on reducing the mortality rate. That result, as well as those mentioned above, confirm that access to treated water is an extremely effective means of reducing the incidence of waterborne diseases and consequently of improving the health of the population.

The results for the other explanatory variables indicate that the relationship between water quality and hospital admission rates is also extremely significant. The results suggest that the worse the water quality, or where the highest percentages of non-standard samples were seen, the higher the hospital admission rates for waterborne diseases. Mattos et al. (2019) also used non-standard chlorine samples as a proxy for water quality. However, their results were not significant. The lagged variable for hospital admissions impacts current admissions. The coefficient suggests that a 1 percent increase in admissions in a given year raises the following year's admissions by 0.66 percent.

For the GDP per capita logarithm, a higher level of income reduces hospital admission rates, as people in these municipalities have more resources and better conditions for preventing contamination. The results show that GDP is very significant for reducing hospital admissions, as a 1 percent increase reduces the rates of hospital admissions caused by wa-

terborne diseases by 98 percent. Sousa and Leite Filho (2008), who used a static model, found a similar result which showed the importance of income in reducing mortality in the Northeastern region. Leivas et al. (2015), using the logarithm of income, also noted the importance of this variable for improving health conditions. The GDP of a region allows for more investments in the health sector, corroborating the results of the study by Costa (2013), which highlights the relationship between GDP per capita and mortality stemming from diarrheal diseases.

Finally, the variable for live births, which is a proxy for the number of children, has a statistically significant and positive relationship. Figure 2 of the previous subsection indicated that the number of children admitted to hospital was higher than that of adults, which is in accordance with a study by Nascimento et al. (2013). Their study showed that the age group most susceptible to contracting waterborne, mainly diarrheal, diseases is precisely that of 1 to 4-year-olds. In consonance with that result, Fink et al. (2011) concluded that children with access to quality water were 8-9 percent less likely to be affected by diarrhea than other children. They also found that in homes connected to the sanitation network, the chances were reduced by 13 percent.

The analysis of the dummies of the states was carried out using the state of Amazonas as the omitted state. As shown in Table 4, on average Amazonas has the lowest rates of hospital admissions for waterborne diseases. The coefficients for the state dummies were positive and statistically significant for all states except Amapá. The aforementioned positive relationship indicates that the rates of hospital admissions in the other states are higher than those of the state of Amazonas.

5. FINAL COMMENTS

Using the dynamic panel method, this study analyzes how access to treated water impacts hospital admission rates due to waterborne diseases in the Legal Amazon region over the 2010-2017 period. The results showed what had already been presented in the literature: access to treated water contributes to a decline in hospital admission rates, which thereby shows that the relationship between sanitation and health conditions is vitally important from the perspective of human capital theory. The main results showed that the worse the water quality, the higher the hospitalization rates for waterborne diseases. Such evidence proves that it does not suffice that the people in the Legal Amazon have access to water, but this water must present minimum levels of quality to reduce the chances of contamination by waterborne diseases. This confirms the importance of basic sanitation as a fundamental tool for improving health conditions.

One contribution of this study is that it presents results for one of the country's most backward regions which has been neglected by the public authorities for decades: the Legal Amazon. It is a region of geographical, cultural, and economic peculiarities which are not always taken into account. It has also been the focus of various other studies, but only related to aspects of environmental preservation. There has been little debate on other vital areas, such as sanitation infrastructure and health conditions, as this study has done.

Another contribution of this paper are the methods used which captures the dynamics

between the present and past of the variables used. However, as pointed out by Hsiao (2003), panel data have certain limitations, one of which refers to the data used in this study. According to Roodman (2009), if the time period, T , is very long, the number of instruments tends to be high, and that could overestimate endogenous variables and lead to failures in the elimination of their endogenous components. In addition, certain municipalities might not have all the necessary information, and that considerably reduces the sample. In such a case, Roodman (2009) states that if the sample, N , is small, the Arellano-Bond autocorrelation test may not be reliable. Therefore, it is very difficult to define the ideal sample. Endogeneity is another issue. Even if the dynamic model allows us to capture this relationship, there could be other endogenous relationships which it does not capture.

In Brazil, there is an enormous gap between health policies and sanitation policies. The results of this study, which present a positive relationship between sanitation and health conditions, reinforce and highlight the need to bring these two policies together, given the complementarity that exists. These results could, therefore, bolster the drafting of complementary public policies for the region, and highlight the importance of the debate on basic infrastructure and the promotion of regional development. In more specific terms, although the 2007 legislation (The Law of National Guidelines for Basic Sanitation - Law 11,445/2007) was an advance for the sector in terms of regulation, the model implemented in Brazil is rather out of date, as it is characterized by inefficiency in company management, uncertainty as to the role of the operational bodies, lack of liaising between federal, state and municipal governments, and lack of long-term planning. In addition, there is a heavy dependence on insufficient federal resources and shortages of financial resources at the regional level. Thus, when investments are made, there is no follow-up or monitoring, and as such investments are generally concentrated in the county's more developed regions, the universalization of basic sanitation is affected.

In a country of continental dimensions, such as Brazil, where the scarcity of resources affects access to sanitation in certain specific regions, the role of those models which allow for participation of the private sector needs to be appreciated. A study carried out by the National Confederation of Industry (Confederação Nacional da Indústria, 2018) showed that the international trend points out that the private sector has a fundamental role to play in expansion, quality enhancement, and efficiency. Thus, encouraging the private sector to participate through the granting of concessions, technical assistance, and public-private partnerships could fill this gap.

In addition, greater flexibility is required so that each local reality is considered. Programs to encourage work in sanitation have already been set up by the federal government for the Northeastern region, but have not yet been extended to the Amazon region. Our results suggest that a program be drawn up for the Legal Amazon with incentives for the private sector to participate, through subsidies for companies to operate in the region, and take their geographical and social specificities into account. Concomitantly, the sector is also affected by a scarcity of quality data. Therefore, a data collection system with greater accuracy should be established to undertake studies, which could lay the foundations for future public policies and for quality long-term planning.

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