WASTE WATER TREATMENT IN THE RECHARGE AND DISCHARGE AREAS OF THE GUARANI AQUIFER

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INTRODUCTION

The main risk for the quality of groundwater bodies is pollution that come from the lack of sanitation and industrial and urban waste in areas of recharge (Follmann and Foleto, 2013). In the context of the Guarani Aquifer, it is extremely important that urban and rural areas have comprehensive sanitation systems that prevent untreated wastewater from being discharged into water bodies (Foster et al, 2009).

There are 368 municipalities located in the recharge and discharge areas of the Aquifer, which vary greatly in terms of size of the population, water supply capacity and – even more – in sewage treatment capacity. There are municipalities that have more than 500,000 habitants, such as Ribeirao Preto and Campo Grande, but there are also very low populated municipalities with fewer than 500 habitants, such as Lagoa Bonita do Sul and Linha Nova. In terms of water supply, the Brazilian Water Supply Atlas of 2010 (ANA, 2010) points that roughly 57% of the municipalities were evaluated as having an adequate system, which means that roughly 43% of the municipalities need to expand their water supply to provide water service to their entire population. Moreover, the Brazilian Sewage Atlas of 2017 (ANA, 2017) point that, in the year 2013, on average, 29% of waste water generated were not even collected to be treated and only 31% of waste water generated were actually treated before being discharges into the basins that straddles the aquifer.

Motta and Moreira (2004) explain that the sanitation operators in Brazil are monopolist licensees that provide services in specific areas of operation, that can be regional or local operators, which increases the complexity of performance debate. This is because we are not only dealing with public or private rationale, but also the trade-offs between local versus state. Those operators are composed by: state companies that supply a pool of municipalities; municipal companies that supply a single or a few closely located municipalities; or private companies that supply a single or a few closely located municipalities but are privately owned (Motta and Moreira, 2004).

Based on this brief context, the main goal of this study is to analyze, using multiple regression analysis, how the 368 municipalities located in the areas of recharge and discharge of the Aquifer, are performing in terms of waste water treatment before discharge into the basins that encompass the aquifer. It is of special interest of this paper to assess whether larger municipalities perform better than smaller ones and whether the category of operator (State Company, Municipal Service or Private Company) show different outcomes in terms of estimated investment needed to enable fully adequate sewage treatment by 2035.

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DATA

The scope of the analysis are the 368 municipalities located in the areas of recharge and discharge of the Guarani Aquifer. We used data from the Brazilian Water Supply Atlas of 2010 (ANA, 2010) and from the

Brazilian Sewage Atlas of 2017 (ANA, 2017). The list of variables that will be used and their description are presented in Table 1.

Table 1. Variable Description

Dependent Variable	
Estimated Investment – Log estimated investments in sewage collection and treatment needed for Municipality to reach proper waste water discharge to the basins by 2035 (BRL).	$\bar{x}$ =15.972 σ =1.302
Independent Variables	
Population (2035) – Log estimated population of the Municipality for the year of 2035.	$\bar{x}$ = 9.344 σ =1.411.
Final Result - Designates if the water supply to the Municipality was evaluated as satisfactory, needs expansion or needs a new spring for the year of 2015.	Municipal Company (38.4%) Private Company (9%) State Company (59.7%)
Category of Operator - Designates if the water supplier of the Municipality was a State Company, a Municipal Service or a Private Company for the year of 2015.	Surface (38.2%) Groundwater (42.3%) Surface and Groundwater (19.5%)
Percentage Removal of Organic Material Needed - Percentage removal of organic material needed to reach proper waste water discharge to the basins by 2035.	Between 60% and 80% (69.8%) More than 80% (21.2%) Complementary solution (3.8%) Joint solution (5.2%)
Kilogram of sewage that was not treated (2013) – Log Kilogram of sewage load discharged with no collection and no treatment in the Municipality per day for the year 2013.	$\bar{x}$ =4.027 σ =2.031.
Kilogram of sewage that was treated (2013) – Log Kilogram of sewage load discharged that were collected and treated per day in the Municipality in 2013.	$\bar{x}$ =4.878 σ =1.541.

ANALYSIS

The regression run the dependent variable Estimated Investment on the independent variables Population (2035); Final Result; Category of Operator; Percentage Removal of Organic Material Needed; Kilogram of sewage that was not treated (2013); and Kilogram of sewage that was treated (2013)). The results of the models are shown in Table 2. Model 1 met the assumptions of linearity and homoscedasticity, but not of normality. Therefore, we used Bootstrap Regression, which does not assume that the variables are normally distributed resampling the data with replacement 1000 times, to provide data-based estimates for standard errors and tests.

Controlling for the other variables, we found a positive association with Population (2035) (β^{hat}=0.374; $p<.001$). Therefore, municipalities that are expected to have a larger population by 2035 are expected to need more investment in sewage collection and treatment than less populated municipalities. The study by Costa et al (2013) advocate that the cost of treating water varies considerably from basins that still have substantial forest cover to basins that don't (Costa et al, 2013). In this sense, municipalities that have urban expansion that do not balance forest protection would be more likely to need larger estimated investment to expand needed sewage treatment facilities.

Furthermore, we found that municipalities that need expansion of the water supply are expected to need greater investment to reach proper sewage collection and treatment by 2035, compared to municipalities that have adequate water supply (β^{hat}= 0.080; p<.05). In the same sense, municipalities that have a greater amount of sewage that is treated today, are expected to need less investment to reach proper sewage treatment by 2035 compared to municipalities that have a more limited sewage treatment system. This is an element that has policy implications in terms of choices (and possibilities) that municipalities make, in the sense that municipalities that chose to invest in sanitation in the past have comparative advantages in terms of the investment needed to reach proper sewage collection and treatment by 2035, compared to municipalities that made (or had to make) different choices.

Table 2. Regression Model with bootstrapped standard errors and tests.

Predictor		Model 1	Bootstrap Model
Population (2035)		0.374***	0.374***
Final Result	Adequate supply		
	System need expansion	0.080	0.080*
	System need new spring	0.054	0.054
Category of Operator	Municipal Company		
	Private Company	0.607	0.607
	State Company	-0.139*	-0.139*
Percentage Removal of Organic Material Needed	Between 60% and 80%		
	More than 80%	0.083	0.083
	Complementary solution	0.226	0.226**
	Joint solution	0.066	0.066
Kilogram of sewage that was not treated (2013)		0.219***	0.219***
Kilogram of sewage that was treated (2013)		-0.174***	-0.174***
Constant		3.224	3.224
R-squared		0.552	0.552

*p < 0.05; **p < 0.01; ***p < 0.001

Finally, we find a negative association with the Category of Operator, when Municipal Company is compared to State Company (β^{hat}= -0.139; p<.05). In this sense, controlling for the other variables, municipalities that are operated by State Companies have 0.139 log units of the estimated investment in sewage collection and treatment needed smaller than municipalities that are operated by Municipal Companies. We can see the effects associated with the Category of Operator to the Estimated Investment expressed in the original units in Figure 1. We can see that state companies are estimated to need less investment to reach proper waste water discharge to the basins by 2035, compared to municipal and private operators. Sabbiani (2008) and Motta and Moreira (2004) explain that state companies in Brazil have better advantage in terms of economies of scale, compared to the other two categories, in which an increase in output does not generate a proportional increase in costs. In fact, Sabbiani (2008) concluded that "a 10% increase in the volume of water produced generates only a 0.98% increase in operating cost" for the regional state-owned operators. Sabbiani (2008) also mention that state companies are able to cross-subsidize between poorer and richer municipalities as they serve a larger pool of municipalities, which is probably unavailable to municipal or private companies in terms of investment.

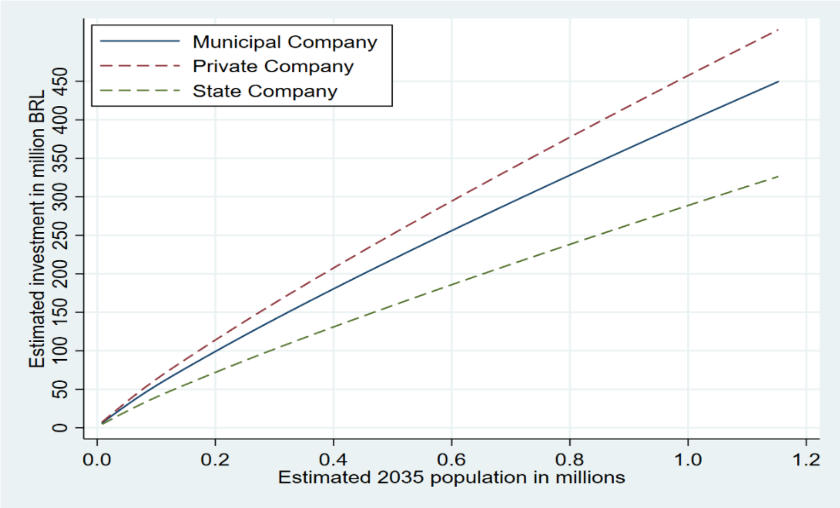

Figure 1. Predicted investment as a function of estimated population of the municipality by 2035 and category of operator. Adjusted margins plots based on the model of Table 2. (Julia H Vieira, 2018)

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