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PRIVATE MEANS BETTER? A WATER AND SANITATION QUASI-EXPERIMENTAL DESIGN

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Abstract:

This paper compares water and sanitation services in municipalities that entered into a concession arrangement with a private operator versus those in a comparable control group of municipalities that continued with a public operator, and we explore five variables of interest: (i) water coverage; (ii) sewage collection; (iii) sewage treatment; (iv) average tariff; and (v) water losses. Using an empirical strategy and making improvements over previous literature, after controlling for municipality peculiarities, we adopt a difference-in-differences model with nearest neighbor matching (NNM) to evaluate private sector management impacts on these variables. We find a greater tariff increase in the first four years after a private operator's start after concession. We only identify weak evidence of greater sewage treatment increase in municipalities that change to a private operator and find no relevant or significant results for the other variables. In terms of policy, this paper contributes with the government clarifying the main benefits of privatizing water and sanitation services.

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JEL Codes: O18; H54; L95; Q53.

PRIVATE MEANS BETTER? A WATER AND SANITATION QUASI-EXPERIMENTAL DESIGN

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ABSTRACT

This paper compares water and sanitation services in municipalities that entered into a concession arrangement with a private operator versus those in a comparable control group of municipalities that continued with a public operator, and we explore five variables of interest: (i) water coverage; (ii) sewage collection; (iii) sewage treatment; (iv) average tariff; and (v) water losses. Using an empirical strategy and making improvements over previous literature, after controlling for municipality peculiarities, we adopt a difference-in-differences model with nearest neighbor matching (NNM) to evaluate private sector management impacts on these variables. We find a greater tariff increase in the first four years after a private operator's start after concession. We only identify weak evidence of greater sewage treatment increase in municipalities that change to a private operator and find no relevant or significant results for the other variables. In terms of policy, this paper contributes with the government clarifying the main benefits of privatizing water and sanitation services.

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1 INTRODUCTION

Depending on each segment's characteristics, in determining the effect of a program on a segment, impact evaluation programs consider different important aspects, such as transparency, public-private partnerships, prices, and privatized industries' performance (Ghulam, 2017; Chauhan et al., 2019 and; Kusi et al., 2020). After Vickers and Yarrom (1991) pointed out that privatizations should be evaluated based on their objectives and the different peculiarities involved in meeting these objectives, empirical research sought to investigate the privatization impacts on different segments and services. The privatizations of water services are a good example. Due to water's relevance for life, the assessment of whether private organizations provide better water access, treatment, and price conditions is pivotal.

According to Galiani et al. (2005), the privatization of water services in Argentina was responsible for an infant mortality decrease, the greater effects of which were realized in the country's poorest regions. Despite the highlighted positive points, the privatization of water companies may not consider important externalities and may harm poorer people through the increase in prices and investments directed with the expectation of greater gain to strategic areas (Estache, Gomez-Lobo and Leipziger 2001; Birdsall and Nellis 2003).

In this paper, we investigate what happens when a municipality changes the water supply and sanitation service from a public entity to a private company in Brazil. We rely on a quasi-experimental design that enables us to reduce selection bias and provide significant comparisons considering five dimensions: (i) water coverage; (ii) sewage collection; (iii) sewage treatment; (iv) average tariff; and (v) water losses.

With data from 2007 to 2018 from The National Information Service on Water and Sanitation (SNIS) for each municipality in Brazil, our results suggest that the average tariff experiences a greater increase when municipalities change from a public to a private operator. There is weaker evidence that sewage treatment has a greater increase in municipalities that change to a private operator, and significant results are observed in years 0, 2, and 4 for one of the methods. The results for water coverage, sewage collection, and water losses are economically but not statistically significant.

Our paper contributes to the literature on water concession in at least two ways. First, our database allows for a concession assessment considering various aspects of water and sanitation services, such as coverage, collection, treatment, tariffs, and loss of use. Second, our study enriches the methodological rigor to measure the results of privatizations in municipalities with different characteristics.

By pointing out that access to water has improved in both privatized and non-privatized regions in countries, such as Argentina, Bolivia, and Brazil, Clarke et al. (2008) and Wallsten (1999) do not allow a conclusion on the effect of the privatization of water services. McKenzie and Mookherjee (2003) point to improved access (but increased prices) when considering countries such as Argentina, Bolivia, Mexico, and Nicaragua.

Using a quasi-experiment approach with controls for time effects, the study by Barrera-Osorio et al. (2009) presented an advance over the findings of Gómez-Lobo and Contreras and Gómez-Lobo and Melendez (2006). For different municipalities in Colombia, using a difference-in-differences model to assess the impact of privatization on access, price, and water quality, the researchers show that privatization is related to water quality improvement and better services. Overall, the results were positive and showed improvements for municipalities in urban and rural areas. However, some municipalities in rural areas showed negative effects on access to water after privatization.

Thus, considering a quasi-experimental approach with better control for the municipalities' individual characteristics, our paper contributes to the previous literature and assesses the impact of private sector management in the water and sanitation segments. Our empirical investigation takes advantage of a regulatory framework change in Brazil in 2007 (Law n. 11.445/07) and its impact on the contracts starting that year onwards. Taking various municipality controls into account, we adopt a difference-in-differences (DiD) model with propensity score matching (PSM) to better compare the impact of private sector management on water and sanitation services.

Moreover, for several reasons, we believe that Brazil provides an excellent scenario to evaluate private sector management effectiveness on water and sanitation services. Law 11.445/07 issued in 2007 is important for the water and sanitation sector regulatory framework in Brazil and allows for concession contracts in competitive bidding processes with regulatory agencies at the regional or local level. Establishing separation guidelines and clearer roles and responsibilities for planning, regulation, and services, the legislation brought significant changes in the sector's institutional arrangement. The planning and granting responsibility of the municipalities was clearly defined such that when granting, the muncipalities could either sign concessions or bilateral contracts with public operators.

The World Health Organization/United Nations Children's Fund (WHO/UNICEF) points out that close to 30% of people worldwide lack access to safe, readily available water at home, and 60% lack safely managed sanitation (WHO/UNICEF, 2017). In Brazil, the water and sanitation sector is lagging behind in responding to the two main challenges that arose in the country in the 20th century: high population growth and high urbanization. There are relevant gaps in the access to water and sanitation services, impacting mostly lower-income households and presenting a barrier to social and economic development.

According to the Fiscal Management Index by *Federação das Indústrias do Rio de Janeiro (FIRJAN)*, from a selection of 4.544 Brazilian municipalities comprising in aggregate 88% of the Brazilian population, close to 86% of the population is in a difficult or critical fiscal situation. Given that water and sanitation services are under the municipalities' responsibility, this is a truly concerning landscape. In addition, due to climate change, the 21st century promises to add complexity, with the water sector, given the effects of flooding on one side and droughts on the other side, being among the most vulnerable sectors (KINGDOM et al., 2018).

2. BRAZILIAN WATER AND SANITATION ACTIVITIES

Generally, in infrastructure services, imperfect information benefits the grantor before the contract's signature and benefits the service provider throughout the term of the agreement. The mitigation of risks and potential conflicts of interest lead to elaborated contracts with proper enforcement mechanisms, the development of which increases transaction costs (MITNICK, 2011). Furthermore, regulatory authorities usually find that the information they need during their planning phase is known by those who will be regulated, thus raising an incentive problem, especially when the objectives of the individual agents do not coincide with the regulator's plans. In such a scenario, when asked to reveal their information, the self-interested agents will deceive the regulator.

Historically, water and sanitation services in Brazil are under the responsibility of the public sector, which is characterised by the following sectoral features: (i) natural monopoly conditions, (ii) relevance of social externalities, and (iii) demand inelasticity (GALIANI et al., 2005).

In Posner (1986), a natural monopoly is defined not by the number of sellers in a specific market but rather by the relationship between the supply and demand for a specific good or service. If all the demand for this specific good or service can be provided at a lower cost by a single seller, this situation denotes a natural monopoly market. This is the case for water and sanitation services, as building any additional network to compete with the existing network would not make sense.

It is widely recognized that water and sanitation services generate externalities on the environment and the living and health conditions of individuals, and the probable effects of the implementation of water and sanitation systems are generally positive for building and providing a service that assures the welfare of the population (CAIRNCROSS, 1989).

Finally, water is essential for the human sustenance of life, and as a mass consumption product, it is generally characterized as having a price inelastic demand. Water expenditure generally constitutes a relatively small proportion of a consumer’s total expenditure, and there are few substitutes for residential water, but there is evidence that its price elasticity may depend on its price structure and that its long-run elasticity is larger than its short-run elasticity (OLMSTEAD et al., 2007; YOO et al., 2014). Although we do not analyze the demand elasticity in the Brazilian municipalities, we investigate whether there is a greater increase in an average tariff in municipalities that change to private operators than in the municipalities that keep a public operator.

In Brazil, the sector plans and initiatives from the mid-20th century to the 1990s counted on the public sector as a funding source and service provider. The National Plan for Water and Sanitation (called Planasa in 1971) created public water utilities at the state level (Cesbs) and centralized resources towards universalization efforts. Unlike the current structure, the structure in the past positioned the responsibility at the state level, and the sector was self-regulated. According to Magalhães (1993), this structure would allow the adoption of differentiated tariff settings to assure cross-subsidies for lower-income consumers. Approximately 70% of the Brazilian population with water access is serviced by Cesbs (SNIS, 2019).

In the 1990s, Brazil had a fiscal crisis that led to constraints on public expenditures. In this context, allowing private investments in infrastructure sectors, concession Law 8.987/1995 was passed and was a landmark in the legal framework. Unlike the power and telecom sectors, the water and sanitation sector had a much slower transition towards private concessionaries because most municipalities had outstanding long-term contracts with public operators and did not have sufficient funds to amortize the investments made by public operators in the case of contract terminations (VARGAS; LIMA, 2004).

Then, Law 11,445 of 2007 provided an important regulatory framework for Brazil's water and sanitation sector. It allowed the elaboration of concession contracts in competitive bidding processes and regulatory bodies at the regional or local level. This law promoted advances in the institutional arrangement of the sector, and the duty to plan, leaving the grant to the municipalities, which were allowed to sign bilateral concessions or contracts with public operators, i.e., the so-called "Program Contract" in Brazil and later defined here as the "Contract Program." Because of the above, privatizations as of 2007 are considered in our paper.

The municipalities are the granting authorities. The service provider is either a public entity (the vast majority can be at the municipal or state level) or a private company. An independent agency is responsible for fiscalization and regulation issues.

The Program Contract is the legal instrument in which one federative entity, such as a municipality, transfers to another public counterpart the responsibility to execute a service. In water and sanitation services, the Program Contract is entered into by the municipality and the public company. Entering into this agreement can only occur after the municipality has developed its own Plan of Water and Sanitation.

This contract sets the terms of the services to be provided, the tariff policy and mechanisms, and the obligations between the contract parts. Law 11.107 from 2005 (known in Brazil as the "Consortium Law") defines that the concession of public services must be granted under the Program Contract when applicable. A Program Contract does not need to be preceded by a licitation process; therefore a Program Contract can be entered into by the parties without being submitted to any competitive process. Furthermore, specific targets for the service provider and milestones under which there could be a termination event are not mandatory for Program Contracts.

Hence, the municipalities must dedicate resources to developing a Plan of Water and Sanitation, the formation of which is a condition precedent to the signing of a Program Contract or to the granting of a concession to a private operator. In that sense, it is possible to argue that poorer municipalities do not have sufficient financial resources and local capabilities to deliver such a plan and to obtain operators. There is inequality among Brazilian municipalities, some of which have universal water and sanitation services, but most lack them.

Providing substantial developments in the regulatory framework and institutional arrangements, Law 4.612 issued in 2019 (approved by the Senate and sanctioned by the President in July 2020) is a game changer for the sector. Under this law, the role of the water and sanitation federal regulatory agency involves issuing guidelines and reference standards for the sector, including, among others, quality and efficiency standards, tariff setting regulations, universalization goals, criteria for regulatory accounting, water loss control guidelines, indemnity calculations, and guidelines related to the governance of regulatory entities. Furthermore, under this law, Program Contracts not preceded by a competitive licitatory process are no longer allowed. This is the most relevant change in dynamics for the sector.

The current contracts will be maintained, but for those contracts that do not have universalization targets with deadlines, the municipalities will have until March 2022 to amend these contracts to have such inclusions. Another relevant change is that smaller municipalities can be aggregated in a block in order to start a licitatory process and obtain service provision collectively with the new law. Each municipality will have a Water and Sanitation Plan. With all these changes in sector dynamics, there is a clear motivation to rerun this study in a few years.

Given the relevance of the water and sanitation segment in Brazil and its changes over time, it is extremely important to assess whether private companies are able to offer better services than state-owned companies.

Buchanan (2003) considers that the government is made up of officials who in addition to pursuing the public interest, also maximize their own utilities. In the context of water and sanitation, one can argue that it is difficult for operators to adjust their tariffs, mainly because of the nature of the good (essential good) and because of the political interest related to the maintenance of a certain approval rate. Additionally, given the institutional arrangement, one can investigate where in this arrangement it is more likely that the officials' interests will prevail over those in the public's interest.

Before Law 11,445 of 2007, the political determinants of water and sanitation service privatization in Brazil were discussed in Saiani (2012), in which the base assumption was that privatizations were used as political strategies. The researcher finds evidence that the probability of privatization increases (i) with the election risk perceived by mayors and (ii) in municipalities in which the mayors are not from a political party that is part of the state governor coalition.

This theoretical framework is relevant for an ex ante analysis of the likelihood of a municipality choosing to open a competitive bidding process. Our goal, on the other hand, is to run an ex post analysis of the private sector management effects. Once the municipality changes from a public to a private operator, the treated group that emerges from concession is compared to the closest comparable control group of municipalities with public operators.

3. DATA

The National Information on Water and Sanitation (SNIS) is a self-declaratory database containing water and sanitation information and indicators for all Brazilian municipalities. The data are available since 2004 through the Brazilian Ministry of Cities ("Ministério das Cidades," currently named "Ministério do Desenvolvimento Regional" or Ministry of Regional Development, hereafter called "MRD") and contain yearly data starting in 1995.

The data can be extracted in both aggregate and disaggregate forms. The data are aggregated by the service provider and consolidated for all the municipalities that are offered services by one specific provider. In the disaggregated form, the individual data for each municipality can be obtained. There are cases in which a municipality can either have just water services or can be serviced by one operator for one service and by another operator for the other service.

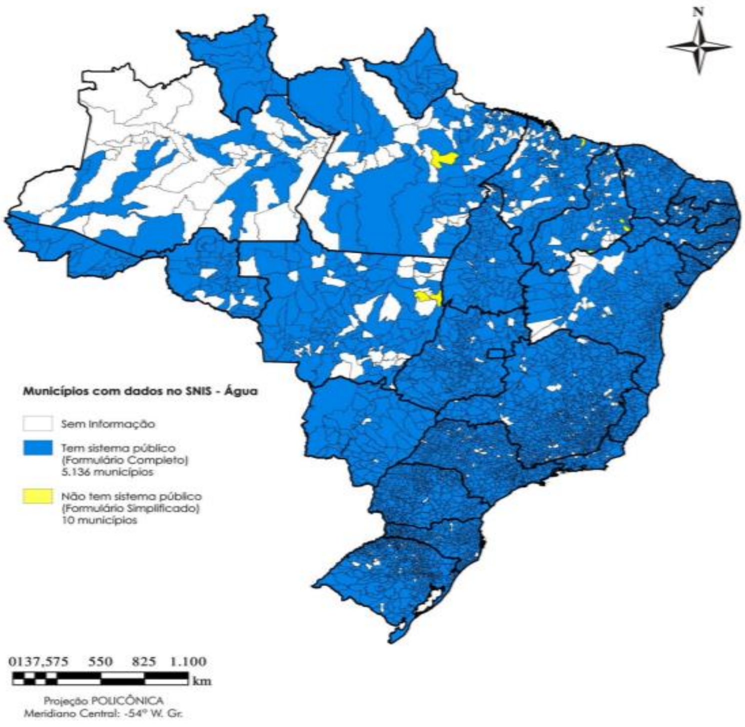
We organize our data considering the disaggregated form for all the available periods. According to the most recent sectoral report provided by SNIS in December 2019, a total of 1,568 service providers fed information into the SNIS Water and Sanitation database in 2018.

For water supply services, in the database, 5,146 municipalities are represented and comprise an urban population of 173.2 million inhabitants, accounting for 92.4% of the total number of municipalities in Brazil and 98.1% of the total urban population in Brazil (see Figure 1 below). For sewage services, 4,050 municipalities are represented and comprise an urban population of 164.1 million inhabitants, accounting for 72.7% of the total number of municipalities in Brazil and 92.9% of the total urban population in Brazil (see Figure 2 below).

The aggregate number for the urban population serviced with water networks was 160.7 million inhabitants in 2018, which represents an increase of 701.5 thousand new inhabitants serviced since 2017 (0.4% growth year over year).

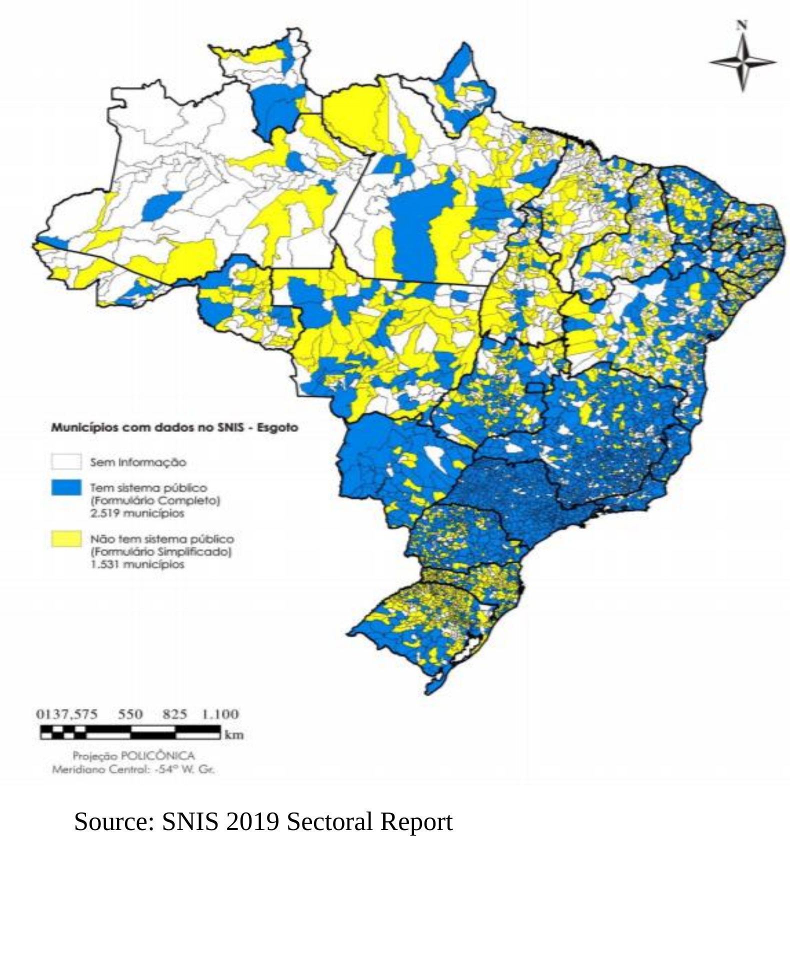
The aggregate number for the urban population serviced with sewage collection was 105.5 million inhabitants in 2018, which represents an increase of 2.0 million new inhabitants serviced since 2017 (1.9% growth year over year). The sewage treatment represents 46.3% of the estimated generated sewage and 74.5% of the collected sewage.

Figure 1. Map of a sample of municipalities with water supply data by type of form, in SNIS in 2018.



Source: SNIS 2019 Sectoral Report

Figure 2. Map of a sample of municipalities with sewage data by type of form, in SNIS in 2018.



Source: SNIS 2019 Sectoral Report

Together, two main points negatively affect the quality of the data in SNIS: (i) self-declaration and (ii) a lack of data standardization. As the data is self-declaratory, it is fair to assume that municipalities with municipal public operators are more likely to have fewer capabilities and financial resources and are also more likely not to deliver any data or to deliver data with poorer quality and/or inconsistencies, due to the lack of monitoring by regulatory agencies.

Regarding the lack of standardization, to improve the SNIS data quality, the Ministry of the Cities (currently MRD) issued Ministerial order no. 719 in December 2018 to establish a methodology for the auditing and certification of SNIS information. The main objective was to determine the information process, level of accuracy, level of confidence, and to share best practices. Consequently, the information is certified in a scale that goes from grades one (minimum level of confidence and accuracy) to seven (maximum level of confidence and accuracy), and includes a grade NC, which stands for "Not Certified." The auditing and certification of the SNIS data are the responsibility of the regulatory authorities at the municipal and state levels. The operators must follow the recommendations of the Water and Sanitation Best Practices Guidelines. Nevertheless, it is important to highlight that as this is an ongoing initiative, there is still some lack of standardization.

As previously mentioned, our variables of interest are (i) water coverage, (ii) sewage collection, (iii) sewage treatment, (iv) average tariff, and (v) water losses. We measure each variable according to the following.

(i) **Water coverage** is the percentage of the total population in the municipality that is serviced with the water supply. It is expressed as a percentage, referenced in the SNIS under the code IN055, and calculated by the formula below.

$$\boldsymbol{Water\ Coverage}\ (\boldsymbol{IN055}) = \frac{AG001}{POPTOT} \times 100 \qquad (1)$$

where the codes are defined as follows.

AG001: Total Population Serviced with Water Supply
POPTOT: Total Population at the municipality (IBGE)

(ii) **Sewage collection** is the volume of collected sewage in the municipality divided by the net water consumption (consumed water minus exported treated water). It is expressed as a percentage, referenced in the SNIS under the code IN015, and calculated by the formula below.

$$\boldsymbol{Sewage\ Collection}\ (\boldsymbol{IN015}) = \frac{ES005}{(AG010 - AG019)} \times 100 \tag{2}$$

where the codes are defined as follows.

ES005: Volume of Collected Sewage
AG010: Volume of Consumed Water
AG019: Volume of Exported Treated Water

(iii) **Sewage treatment** is the total volume of sewage (treated sewage plus raw exported sewage) divided by the net water consumption (consumed water minus exported treated water) in the municipality. It is expressed as a percentage, referenced in SNIS under the code IN046, and calculated by the formula below.

$$\boldsymbol{Sewage\ Treatment}\ (\boldsymbol{IN046}) = \frac{(ES006 + ES015)}{(AG010 - AG019)} \times 100 \tag{3}$$

where the codes are defined as follows.

ES006: Volume of Treated Sewage
ES015: Volume of Raw Exported Sewage Treated at Importer Installations
AG010: Volume of Water Consumed
AG019: Volume of Exported Treated Water

(iv) **The average tariff** is the total water and sewage revenue divided by the volume of billed water and sewage. It is expressed in Brazilian Reais per cubic meter, referenced in SNIS under the code IN004, and calculated by the formula below.

$$\boldsymbol{Average\ Tariff}\ (\boldsymbol{IN004}) = \frac{(FN002 + FN003 + FN007 + FN038)}{(AG011 + ES007) \times 1000} \tag{4}$$

where the codes are defined as follows.

FN002: Direct Operational Water Revenue
FN003: Direct Operational Sewage Revenue
FN007: Direct Operational Exported Water Revenue (Raw or Treated)
FN038: Direct Operational Raw Imported Sewage Revenue
AG011: Volume of Billed Water

ES007: Volume of Billed Sewage

(v) **Water loss** is the difference between the total water (produced and imported) and the consumed water (including for operational services) divided by the two-year average of the active connections in the municipality. It is expressed in liters per day per connection, referenced in SNIS under the code IN051, and calculated by the formula below.

$$\textbf{Water Loss } (\boldsymbol{IN051}) = \frac{AG006 + AG018 - AG010 - AG024}{\frac{AG002 + AG002_A}{2}} \times \frac{1{,}000{,}000}{365} \quad (5)$$

where the codes are defined as follows:

AG006: Volume of Produced Water
AG018: Volume of Imported Treated Water
AG010: Volume of Consumed Water
AG024: Volume of Service
AG002: Quantity of active water connections in the reference year
$AG002_A$: Quantity of active water connections in the previous year

While the first three variables are related to the provision of water services in sanitation, they are far from covering the whole spectrum of the performance goals expected to be defined in a concession agreement. There are also additional goals, such as targets for water quality and the intermittence of the water supply. These other variables were considered but were not chosen because of the low quality of the SNIS data and the much smaller sample.

Water loss is a valid way to assess a water and sanitation operator's efficiency because the revenue of an operator is based on the billed water, and the cost is based on the produced water. Hence, it is of interest for the operators to minimize water losses.

The average tariff is the key variable used to assess what consumers are paying and how the tariff is increasing over time. It would be expected that if there is a greater tariff increase in municipalities with a private operator than in those with a public operator, at least one of two things would have happened: (i) the private operator achieved goals in the contract and obtained a tariff increase through a parametric formula stipulated in the contract, while the public operator did not, and/or (ii) the private operator had a different treatment for tariff readjustments. If (i) happened, it would be expected that at least one of the other four variables being studied had shown an improvement compared to those of a municipality with a public operator. Nevertheless, it could also happen that none of these four variables had shown an improvement and that another variable not captured here in this work had improved. As mentioned before, the choice of variables was mainly driven by their relevance and the ability to assess the quality of the data in SNIS for the given variable. If (ii) happened, it could mean that the asymmetry in treatment was related to regulatory differences, which in the case of water and sanitation is truly likely since the regulation is decentralized and with different degrees of political influence in the regulatory agencies, can be done at the municipal or state level.

From 2007 (the period after Act 11.445) to 2018, we have found 89 concessions in our dataset. To be considered concession, a given municipality must change the legal nature of the operator from a public operator to a private operator in a given year. Table 1 shows for each period the number of concessions accompanied by the number of valid entries for each of the five variables previously described.

Table 1. Concessions per year and valid entries for our variables of interest

Year	Concessions per period	Water Coverage (IN055) - with input	Sewage Collection (IN015) - with input	Sewage Treatment (IN046) - with input	Average Tariff (IN004) - with input	Water Loss (IN051) - with input
1995 to 2006	174	151	22	16	159	138
2007	3	0	0	0	0	0
2008	14	13	3	3	10	10
2009	3	3	1	1	3	3
2010	5	5	3	2	4	5
2011	5	5	3	2	4	5
2012	6	6	4	3	6	6
2013	5	5	2	2	5	5
2014	5	5	1	1	5	4
2015	15	15	7	7	15	15
2016	6	6	3	2	6	5
2017	4	4	2	2	4	4
2018	18	18	7	7	18	18
Total 1995 - 2018	**263**	**236**	**58**	**48**	**239**	**218**
Total 2007 - 2018	**89**	**85**	**36**	**32**	**80**	**80**

Source: SNIS.

The average tariff was deflated based on the Brazilian Consumer Price Index ("*Índice de Preços ao Consumidor Amplo*", or IPCA, calculated *by Instituto Brasileiro de Geografia e Estatística*, IBGE), is expressed in real terms; thus, this variable will hereafter be called the "Average Real Tariff".

Each dependent variable is analyzed from the year of concession (defined as Year 0) to Year 4 of the contract. The rationale for this is that when a new private operator takes over a concession, it will carry a cycle of investments in the first years of the concession to (i) meet concession targets and contractual obligations, (ii) be able to claim any adjustment of tariff over the inflation and (iii) implement operational improvements (such as a reduction in water losses, also known as non-revenue water) that will be measurable. It is possible to assume that this first cycle of investments takes from two to four years, thus justifying the analysis period.

After looking at the database and dropping observations with incorrect inputs (such as coverage numbers below zero or above 100%), the number of observations showed a tiny drop. Table 2 presents the number of observations for water coverage, average real tariff, water losses, sewage collection, and sewage treatment.

Table 2. Descriptive Statistics

Descriptive Statistics - Clean Database (2007 to 2018)

Variable	Observations	Mean	Median	Std. Dev.	Min	Max
Water Coverage (IN055)	75.43	66.52	69.49	24.82	0.00	100.00
Sewage Collection (IN015)	25.56	54.89	61.74	29.81	0.00	100.00
Sewage Treatment (IN046)	25.58	38.39	33.06	33.26	0.00	100.00
Average Real Tariff (IN004)*	71.11	0.91	0.81	0.53	0.11	47.13
Water Loss (IN051)**	7339	270.7	164.7	333.06	0.00	4079.54

*Expressed in Brazilian Reais per cubic meter. Deflated by Brazilian Consumer Price Index IPCA.
**Expressed in Liters per day per connection.

Water Coverage, Sewage Collection and Sewage Treatment are expressed in percentage points.

Source: SNIS.

4. EMPIRICAL STRATEGY

We evaluate the private sector management effect on water and sanitation by using a difference-in-differences model. Note that if the program or policy is not random, the selection bias problem arises. This is exactly the case for municipalities that undergo a competitive process and end up with a private operator; i.e., if the program is random, every municipality can choose between keeping a contract with the public operator under the Program Contract or opening a competitive bidding process in which a private operator might win.

Possibly, the selection in such a case may not be random, and analyzing the municipalities' behavior with a private operator may bring a bias to the evaluation result. The municipalities that choose to do so (the treatment group) might present favorable features to the results, which would lead to a positive bias of the results. To mitigate such selection bias, a control group needs to be used. A control group is a group that did not undergo the same program or policy (in this case, a municipality that continued with a public operator). The selection of the control variables that determine the control group is linked to the analysis's success. An unbiased estimate of the average treatment effect is not obtained by directly comparing outcomes between the two treatment groups. The propensity score can estimate the average treatment effects.

As defined in Rosenbaum and Rubin (1983), the propensity score is the probability of treatment assignment conditional on observed baseline covariates and is basically a balancing score in which the distribution of measured baseline covariates is similar between treated and untreated individuals conditional on the propensity score. It is used to attenuate the confounding factors when the effects of treatments are estimated. After the matched sample is formed, the treatment effect is estimated by comparing outcomes between the treated and non-treated subjects. In the case of continuous outcomes, the treatment's effect can be estimated as the difference between the mean outcome for treated subjects and the mean outcome for the non-treated subjects in the matched sample.

According to Rosenbaum and Rubin (1985), nearest neighbor matching (NNM) is useful when selecting non-treated subjects whose propensity score is close to that of a treated subject. NNM selects for matching to a treated subject the non-treated subjects whose propensity score is closest to it. When multiple non-treated subjects have propensity scores equally close to those of the treated subjects, a non-treated subject is selected randomly.

The use of propensity score matching (hereafter “PSM”) for such experiments is consistent with Smith and Todd (2005), Rosenbaum and Rubin (1983), Rosenmaum and Rubin (1985), and Heckman, Ichimura, and Todd (1997).

Considering the above, the proposed method to evaluate a private operator's entrance in a municipality is to use NNM and PSM. The method evaluates the behavior of treated and non-treated (control) municipalities before and after the treatment, considering that the treated and control municipalities would have the same evolution in case there was no treatment.

Taking Y_{it} as the variable of interest (water coverage, sewage collection, sewage treatment, average tariff, and water losses) at municipality i at moment t, the possible outcomes are Y_{it}^1 if the municipality starts being serviced by a private operator and Y_{it}^0 if the municipality does not change to a private operator (i.e., the control group). Treatment is a dummy in which $D = 1$ if the municipality starts being serviced by a private operator and $D = 0$ if it does not. Only Y_{it}^1 or Y_{it}^0 can be observed for each municipality; therefore, it is not possible to directly measure $Y_{it}^1 - Y_{it}^0$.

The average treatment effect on the treated (ATT) is calculated as follows:

$$\boldsymbol{ATT} = E[Y_{it}^1 - Y_{it}^0 \mid D = 1] = E[Y_{it}^1 \mid D = 1] - E[Y_{it}^0 \mid D = 1] \qquad (6)$$

With the inclusion of a matrix of covariates X_it, which is independent of treatment D, the selection bias can be reduced:

$$\boldsymbol{ATT} = E\left[Y_{it}^1 - Y_{it}^0 \left| X_{it}\, x\, D = 1\right] = E[Y_{it}^1 \left| X_{it}\, x\, D = 1\right] - E[Y_{it}^0 \left| X_{it}\, x\; D = 1\right] \qquad (7)$$

We can define the parameter of interest α as follows:

$$\boldsymbol{\alpha} = E\left[Y_{it}^1 \middle| X_{it}\, x\, D = 1, t = 1\right] - E\left[Y_{it}^1 \middle| X_{it}\, x\, D = 1, t = 0\right] -$$
$$-\left\{E\left[Y_{it}^0 \left| X_{it} x\, D = 1, t = 1\right] - E\left[Y_{it}^0 \left| X_{it}\, x\, D = 1, t = 0\right]\right\} \qquad (8)$$

After taking the observable differences in the treatment and control groups into account, we can gauge the impact of private sector management of water and sanitation services (Y_{it}). Hence, our difference-in-differences model can be expressed as follows:

$$\boldsymbol{Y_{it}} = \beta_0 + \beta_1 x D_i + \beta_2 x T_t + \beta_3 x X_{it} + \alpha x D_i x T_t + \varepsilon_{it}, \tag{9}$$

where:

D_i is a treatment dummy (private sector management),
T_t is a dummy that assumes a value equal to 1 from the first contract year of a private operator thereafter, and
X_{it} *is a* matrix of control variables that measure observable characteristics of the municipalities

The matrix of control variables Xit includes (i) the microregion of each municipality (fixed characteristic for each municipality); (ii) the logarithm (ln) of the population for each year; (iii) the municipal GDP per capita for each year; and (iv) the normalized year data, in which the year = 0 for every first year of a private contract in the treated group and year = 0 is locked in 2007 for the control group. Our data are from the Brazilian Institute of Geography and Statistics (IBGE). Furthermore, every municipality that had concession anytime in the SNIS database from 1995 onwards was excluded from the control group. We did this to avoid having a municipality that changed to a private operator from 2007 to 2018 paired with a municipality that made such a change before 2007.

We test the control variables to analyze the matching quality, and diagnostic statistics are used to check for the covariate balance over the treatment groups after estimation. The test brings the model-adjusted difference in means and the ratio of variances between the treated and non-treated for each covariate. The desire is that the matched standardized differences are closer to zero than are the raw standardized differences and that the matched variance ratio is closer to one than the raw variance ratio is. One can see in Table 3 that compared to PSM, NNM presents overall better results for this balancing test.

Table 3. Control Variables Covariate Balance Summary

This table presents the effectiveness of the control variables used for matching in Year 0. It compares the standardized differences and variance ratio of the raw and matched data. The expectations are to find that compared to the standardized differences of the raw data and the variance ratio of the raw data, the standardized differences of the matched data are closer to zero and the variance ratio of the matched data is closer to one.

Control Variable	**Standardized Differences**		**Variance Ratio**	
	Raw	**Matched**	**Raw**	**Matched**
Average Real Tariff				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Microregion	-0.1148	-0.0842	0.7174	0.8978
ln population	0.6022	0.0852	1.2421	0.8330

GDP per capita	0.9502	0.1037	4.0781	0.8068
Propensity Score Matching (Logit treatment model, 1:1 match)				
Microregion	-0.1148	0.2249	0.7173	1.2540
ln population	0.6022	0.0036	1.2421	0.6387
GDP per capita	0.9502	0.2635	4.0781	0.9541
Water Coverage				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Microregion	-0.6920	-0.0750	0.6565	0.8874
ln population	0.6683	0.0890	1.1339	0.7250
GDP per capita	0.8806	0.0776	3.8775	0.8184
Propensity Score Matching (Logit treatment model, 1:1 match)				
Microregion	-0.0692	0.2021	0.6565	1.2652
ln population	0.6683	0.0398	1.1339	0.6276
GDP per capita	0.8806	0.1920	3.8775	0.9315
Sewage Collection				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Microregion	-0.0086	-0.0316	0.8360	0.9466
ln population	0.5355	0.1104	0.8179	0.6261
GDP per capita	0.9432	0.1687	2.0296	0.6924
Propensity Score Matching (Logit treatment model, 1:1 match)				
Microregion	-0.0086	0.2553	0.8360	1.1213
ln population	0.5355	-0.1411	0.8179	0.4758
GDP per capita	0.9432	0.2769	2.0296	0.8245
Sewage Treatment				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Microregion	-0.0715	-0.0341	0.7856	0.9367
ln population	0.4973	0.1086	0.8271	0.6251
GDP per capita	0.9328	0.1725	2.1165	0.7044
Propensity Score Matching (Logit treatment model, 1:1 match)				
Microregion	-0.0715	0.2547	0.7856	0.9654
ln population	0.4973	-0.0764	0.8271	0.4232
GDP per capita	0.9328	0.2335	2.1165	0.7532
Water Losses				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Microregion	-0.1039	-0.0817	0.7100	0.8928
ln population	0.6259	0.0890	1.2456	0.7355
GDP per capita	0.9227	0.1045	3.9542	0.7983
Propensity Score Matching (Logit treatment model, 1:1 match)				
Microregion	-0.1039	0.1885	0.7100	1.3429
ln population	0.6259	0.0386	1.2456	0.6362
GDP per capita	0.9227	0.2038	3.9542	0.8189

Source: Own elaboration.

A propensity score is a conditional probability of treatment. The NNM algorithm implements the NNM estimator for the ATE and the ATT. This estimator is derived by Abadie and Imbens (2006) and uses the distance metric Mahalanobis. To test the robustness of the results, a placebo test was performed in which all the treated samples were removed from the sample and a random subset of the non-treated samples was assigned to the treatment group. Both NNM and PSM were performed from Year 0 to Year 4 to analyze the significance and trajectory of the variables under this placebo test and compare it to the original treatment group. Finally, NNM and PSM were performed on all the treated patients one year before concession (Year 1) to identify whether the treatment can explain the coefficient obtained in Year 0. We find that NMN and PSM results are quite similar in our study. Hence, we decided to show only NMN thereafter.

5. RESULTS

Table 4 shows the private sector management effects on the average real tariff. One can perceive the social benefit of the private concession through the tariff charged. We see that the average real tariff set for the private concession is lower than the public entity. However, we find evidence of more tariff increases in the first four years of a municipality with a private operator than in a municipality with a public operator. This is because the coefficients increase from -0.3361 in Year 0 to -0.2073 in Year 4 in the NNM model, are all significant at 1%, have the same signal throughout these years, and have an increasing trajectory. It is possible to argue that part of the private efficiency goes to the user, but the price difference aforementioned decreases over time, indicating that the public entity is more discretionary and does not efficiently correct the tariff charged through time. We found the same results in the PSM model. In line with expectations, there are no significant results observed in the placebo test.

Table 4 - Private Sector Management Effects on Average Real Tariff

This table presents the NNM results for Average Real Tariffs in Brazilian municipalities after the private sector management of water and sanitation services. The control variables are the following: (i) ln(population), (ii) municipal gdp per capital, (iii) microregion, (iv) normalized year. The placebo test removed all the treated subjects from the sample and assigned treatment to the non-treated group randomly. The symbols *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively

Variable: Average Real Tariff	Coefficient	Robust Standard Error	95% Conf. Interval	
Treatment Effect				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	-0.3361***	0.0768	-0.4866	-0.1855
Year 1	-0.2712***	0.0516	-0.3722	-0.0170
Year 2	-0.2998***	0.0400	-0.3783	-0.2214
Year 3	-0.2207***	0.0500	-0.3188	-0.1227
Year 4	-0.2073***	0.0448	-0.2952	-0.1194
Placebo Test (treatment assigned randomly for the subset of non-treated)				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	0.1403	0.0880	-0.1584	0.1865
Year 1	0.3862	0.0925	-0.1427	0.2199
Year 2	-0.0624	0.0932	-0.2451	0.1204
Year 3	-0.0446	0.0850	-0.2112	0.1220
Year 4	0.0101	0.0983	-0.1825	0.2027

Although not statistically significant, Table 5 shows an improvement in water coverage coefficients over time. One can see that most confidence interval parts are positive, confirming the economic significance of the results. The placebo test was also performed, and aligned with expectations, it produced no statistically significant result.

Table 5 - Private Sector Management Effects on Water Coverage

This table presents the NNM results for Water Coverage in Brazilian municipalities after the concession of water and sanitation services. The control variables are as follows: (i) ln(population), (ii) municipal GDP per capita, (iii) microregion, (iv) normalized year. The placebo test removed all the treated subjects from the sample, and assigned treatment randomly to the non-treated group . The symbols *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively.

Variable: Water Coverage	Coefficient	Robust Standard Error	95% Conf. Interval	
Treatment Effect				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	-2.5353	5.7213	-13.7488	8.6782
Year 1	-0.0065	4.5004	-8.8271	8.8141
Year 2	0.4081	4.8783	-9.1531	9.9693
Year 3	5.2061	4.8695	-4.3379	14.7501
Year 4	6.8894	4.8838	-2.6827	16.4614
Placebo Test (treatment assigned randomly for subset of non-treated)				

Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	-3.3292	3.1042	-9.4133	2.7548
Year 1	-2.6731	2.6628	-7.8922	2.5460
Year 2	-0.8485	3.1629	-7.0477	5.3508
Year 3	-3.0123	2.9542	-8.8025	2.7779
Year 4	-4.1584	2.9089	-9.8597	1.5429

Table 6 shows the private sector management effects on sewage collection. Compared to data on average tariff, water coverage, and water losses, the data for both sewage collection and sewage treatment in SNIS have lower availability and poorer quality. There is no consistency in the coefficients trajectory throughout Year 0 to Year 4 in NNM. In addition, in line with expectations, there are no significant results in the placebo test.

Table 6 - Private Sector Management Effects on Sewage Collection

This table presents the NNM results for Sewage Collection in Brazilian municipalities after the concession of water and sanitation services. The control variables are as follows: (i) ln(population), (ii) municipal GDP per capita, (iii) microregion, (iv) normalized year. The placebo test removed all the treated subjects from the sample, and assigned treatment randomly to the non-treated group. The symbols *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively.

Variable: Sewage Collection	**Coefficient**	**Robust Standard Error**	**95% Conf. Interval**	
Treatment Effect				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	15.1451***	5.5510	4.2655	26.0249
Year 1	0.9298	11.1615	-20.9463	22.8059
Year 2	9.8138	9.8209	-9.4348	29.0625
Year 3	8.7728	8.2003	-7.2994	24.8451
Year 4	21.3653***	7.9181	5.8461	36.8845
Placebo Test (treatment assigned randomly for subset of non-treated)				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	-7.9878	8.0007	-23.6690	7.6933
Year 1	-9.0843	7.5787	-23.9382	5.7697
Year 2	-11.3904	8.2729	-27.6049	4.8242
Year 3	-11.6874	8.1123	-27.5873	4.2125
Year 4	-11.3424	8.1051	-27.2282	4.5433

Table 7 displays the private sector management effects on sewage treatment. One can see statistically significant results in the NNM model; these results show a coefficient of 16.43 in Year 0, 18.41 in Year 2, and 24.68 in Year 4, which could provide some evidence that sewage treatment is increasing in the first four years of a municipality that changed to a private operator.

These results are aligned with what was expected. The placebo test produced some statistically significant results at 10% but with negative coefficients.

Table 7 - Private Sector Management Effects on Sewage Treatment

This table presents the NNM results for Sewage Treatment in Brazilian municipalities after the concession of water and sanitation services. The control variables are as follows: (i) ln(population), (ii) municipal gdp per capital, (iii) microregion, (iv) normalized year. The Placebo Test removed all the treated subjects from the sample and assigned treatment to the non-treated randomly. The symbols *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively

Variable: Sewage Treatment	Coefficient	Robust Standard Error	95% Conf. Interval	
Treatment Effect				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	16.4345**	7.1280	2.4639	30.4051
Year 1	7.4945	11.6843	-15.4062	30.3952
Year 2	18.4110*	11.1406	-3.4242	40.2461
Year 3	14.4357	9.5697	-4.3205	33.1920
Year 4	24.6802**	10.2057	4.6774	44.6831
Placebo Test (treatment assigned randomly for subset of non-treated)				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	-6.1596	8.1733	-22.1791	9.8599
Year 1	-10.1810	6.0306	-22.0008	1.6388
Year 2	-12.1545*	6.3796	-24.6584	0.3494
Year 3	-11.4336*	6.3887	-23.9552	1.0879
Year 4	-10.2879	6.3935	-22.8190	2.2432

Finally, for water losses, we find no consistency in the trajectory throughout the years, as per Table 8 below.

Table 8 - Private Sector Management Effects on Water Losses

This table presents the NNM results for Water Losses in Brazilian municipalities after the concession of water and sanitation services. The control variables are as follows: (i) ln(population), (ii) municipal gdp per capital, (iii) microregion, (iv) normalized year. The Placebo Test removed all the treated subjects from the sample and assigned treatment randomly to the non-treated group. The symbols *, ** and *** indicate statistical significance at 10%, 5% and 1%, respectively

Variable: Water Losses	Coefficient	Robust Standard Error	95% Conf. Interval	
Treatment Effect				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	-34.4032	26.1799	-85.7148	16.9084
Year 1	-33.3955	37.0688	-106.0490	39.2580
Year 2	-18.3004	33.0258	-83.0297	46.4289
Year 3	33.4594	50.8047	-66.1160	133.0348
Year 4	28.4311	56.0950	-81.5131	138.3752

Placebo Test (random treatment for subset of non-treated)				
Nearest Neighbor Matching (Mahalanobis distance metric, 1:1 match)				
Year 0	-1.5490	44.4335	-88.6371	85.5390
Year 1	12.8231	46.4326	-78.1832	103.8293
Year 2	-16.1168	48.3461	-110.8734	78.6398
Year 3	-35.9977	46.0506	-126.2552	54.2599
Year 4	-66.2214	38.0182	-140.7356	8.2929

Collectively, the results point to an increase in tariffs and poor results for improvements in sewage treatment after concession. Thus, the results contribute to the findings by Clarke et al. (2008) and Wallsten (1999) in their analysis of the effects of privatization on water services for municipalities with and without privatized services.

Our study corroborates part of the findings of McKenzie and Mookherjee's (2003) study on signaling price increases. Additionally, it contributes to the Gómez-Lobo and Contreras (2003), Gómez-Lobo and Melendez (2006), and Barrera-Osorio et al. (2009) research in which controls were used for the specific characteristics of each municipality. Finally, the findings contribute to the literature by jointly exploring the effects of private sector management on water and sewage services.

6. FINAL REMARKS

This paper evaluated the private sector management effects of water and sanitation services in the first four years after the municipalities changed from a public to a private operator and focused on five variables of interest: (i) water coverage; (ii) sewage collection; (iii) sewage treatment; (iv) average tariff; and (v) water losses. While the first three variables are related to the provisions of water services and sanitation itself, the average tariff is the key variable to assess what consumers are paying and how the tariff is increasing over time. Water losses are good for assessing the efficiency of a water and sanitation operator. After a brief overview of the sector and its regulatory framework, due to Law number 11.445 issued in 2007 and the changes to the regulatory framework, the period of interest selected was the period from 2007 to 2018.

Using a difference-in-differences model with nearest neighbor matching (NNM), we apply controls for microregion, population, and GDP per capita. We also test our model's robustness with a placebo test in which all the treated samples were removed from the sample, and a random subset of the non-treated samples was assigned treatment.

Our results point to tariff increases in the first four years for a municipality after concession compared to a municipality with a public operator, which show significant results in all years. No significant results were observed in the placebo test for the average tariff variable. In addition, the negative coefficient for that variable in the concession year cannot be explained by the concession itself since the treatment effect application for the year before the concession has a similar result.

Although this paper does not investigate this issue, it would be interesting for further studies to investigate whether (i) the private operator achieved goals in the contract and obtained a tariff increase through a parametric formula stipulated in the contract, while the public operator did not achieve these goals, or (ii) if the private operator has a different treatment for tariff readjustments than the public operator. It is important to note that the lack of public data, the decentralization of the regulatory agencies, and the lack of standardization of contracts and targets pose significant challenges for such analysis.

We find weaker evidence that sewage treatment increases in the first four years in a municipality with a private operator after concession compared to a municipality with a public operator, and significant results are found in Year 0, Year 2 and Year 4 of the NNM model. For the remaining three variables (i.e., water coverage, sewage collection, and water losses), the results are not statistically significant and/or do not have a consistent trajectory throughout the years.

Finally, as Law 4.612 issued in 2019 has been approved and for the sector should be a game changer resulting in substantial developments to the regulatory framework and institutional arrangements, there is a clear motivation to rerun this study in a few years and check the effects of the private sector management after the implementation of this new law.

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