EFFICIENCY IN THE BRAZILIAN SANITATION SECTOR

Forthcoming in Utilities Policy

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This paper examines the relative efficiency of regional (state) and three different types of local (municipal) enterprises in providing water and sewerage services in Brazil between 2000 and 2004. First, a cost function is estimated employing a fixed effects panel data model. Second, the firm-specific costs from the first stage are explained by means of firm-type indicator variables. The results show that the Regional state-owned providers have the lowest firm-specific costs, reinforcing the savings they achieve from actual economies of scale. The study also shows that local Private operators have similar firm-specific costs than local Public-Corporative providers, while local Public-Non-Corporative providers have the highest firm-specific costs.

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1. Introduction

Early work on the relative performance of water and sewerage (WS) utilities by Crain and Zardkoohi (1978) tried to determine whether private U.S. water utilities attained a more efficient level of operation than public ones. Since then, a number of papers have been published on the efficiency of WS utilities. Some authors have also focused on the private vs. public issue, while others have tested other hypotheses, like the existence of economies of scale, economies of scope, or the possible homogeneity or homotheticity in the production technology. Data availability limited the types of studies: early papers focused mostly on utilities in the U.K. and U.S. because these countries pioneered the collection and publication of data on WS firms.

Until a decade ago, little research was conducted into the efficiency of WS utilities in developing countries. Then, studies began to address the performance of water systems using quantitative techniques. A number of papers focused on Asian and African water utilities, most of them supported by the World Bank.[1] These studies provided insights for countries implementing World Bank policies to increase coverage and quality of WS services in their regions.

Politically potent and economically important, WS utilities generate public concern over efficiency. Using data from Brazil, this study extends the standard approach by comparing not only the performance of public and private WS firms, but also the performance of different types of publicly owned WS operators.

There are four different types of WS providers in Brazil. The first type consists of regional state-owned operators, which provide services at the state level. They are called

[1] For example, Estache and Rossi (1999), Estache and Rossi (2002), and Estache and Kouassi (2002).

Regional firms hereafter. The other three types of WS operators provide services at the local (municipal) level. The first local type consists of private firms that have signed concession contracts with the municipalities where they operate. They are called Private firms throughout this study. The remaining two local types both consist of municipally-owned operators, but they differ in their legal status. One type consists of local public providers that are organized similarly to a corporate business. They are called Public-Corporative operators hereafter. The remaining type consists of local public providers that are run like not-for-profit organizations. They are called Public-Non-Corporative providers throughout this study.

Besides the public vs. private ownership discussion, controversy exists in Brazil about whether municipalities or states should be responsible for WS provision. The Association of State-Owned Sanitation Firms (AESBE), for example, argues that WS services should be provided at the state level for two reasons: one, the larger scale of operation permits scale economies; two, there is a possibility of cross-subsidization between poorer and richer municipalities.[2] In contrast, the National Association of Municipal Sanitation Services (ASSEMAE) favors municipal provision on the grounds that WS services are an essential necessity for the population.[3] ASSEMAE does not explain in detail why the essential nature of WS services calls for municipal and not state provision, but standard arguments are based on local control, responsiveness to citizen concerns and awareness of local conditions.

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[2] Associação das Empresas de Saneamento Básico Estaduais. See http://www.aesbe.org.br (last visit: March 26, 2007).

[3] Associação Nacional dos Serviços Municipais de Saneamento. See http://www.assemae.org.br (last visit: March 26, 2007).

This study finds that WS provision in Brazil is characterized by economies of scale. Therefore, since an increase in output generates a less-than-proportional increase in costs, WS provision at the state level should be preferred. The potential efficiency gains are not trivial when one recalls that Brazil has a population of 187-million people.

In a first stage, this paper employs a fixed effects panel data model with data for 2000-2004. A cost function is proposed, identifying firm-specific (operating) costs which account for inefficiency and other unobserved heterogeneity. In a second-stage, those firm-specific costs are explained by means of firm-type and other time-invariant indicator variables (e.g., location). The results show that Regional operators have lower firm-specific costs than all other types of WS providers. This finding indicates that the efficiency gains of the state providers from their scale of operation are augmented by their lower firm-specific costs. The results also show that the public vs. private efficiency comparison depends on how the local public provider is organized. According to this study, Private and Public-Corporative providers have lower firm-specific costs than Public-Non-Corporative providers. This finding indicates that the WS operators organized as not-for-profit organizations (i.e., the Public-Non-Corporative type) have the highest firm-specific costs in Brazil.

In spite of the firm-specific cost differences found, it is worth mentioning that these differences represent a very small portion of operating costs. The first-stage regressions illustrate that the output produced, input prices and other technological factors explain most of the variation of operating cost, regardless of the firm-type. As a result, although statistically significant, the differences in firm-specific costs are not substantial from an economic point of view.

Quantifying the relative efficiency of the Brazilian regional operators, Tupper and Resende (2004) use Data Envelopment Analysis (DEA) with data for 1996-2000. The efficiency scores obtained are considered in the construction of a proposed linear reimbursement rule that constitutes a yardstick mechanism. However, the authors acknowledge that its implementation is constrained by the weak current regulatory framework. Utilizing DEA with data for 1998-2002, Seroa da Motta and Moreira (2006) argue that the government level at which conceding authority resides is not a crucial barrier to the Brazilian sanitation sector's development when looking at the operators' performance. Unlike this study, they find that ownership does not matter for productivity gains for municipal services. Like this paper, they find that Regional operators benefit from larger scale economies.

Evidence on the beneficial effects of private sector participation (PSP) in the Latin American sanitation sector is not conclusive. In Argentina, Bolivia and Brazil, for example, Clarke et al. (2004) find that even when connection rates to piped water improved following the introduction of PSP, connection rates similarly improved in the control regions that never privatized. In contrast, Galiani et al. (2005) find that child mortality in Argentina fell 8% in the areas that privatized their water services. They conclude that while privatization is associated with reductions in deaths from infectious diseases, it is uncorrelated with deaths from causes unrelated to water conditions. The ambiguity on the beneficial effects of PSP in the Latin American sanitation sector coincides with the results from other regions.[4]

[4] For the US, Bhattacharyya, Parker and Raffiee (1994) found evidence of greater efficiency in public utilities, Crain and Zardkoohi (1978) found evidence in favor of private operators, and Byrnes et al. (1986), Feigenbaum and Teeples (1984) and Fox and Hofler (1986) found no difference between public and private operators. For Asia, Estache and Rossi (1999) found evidence in favor of private operators

This paper first presents an overview of Brazil's water and sewerage industry. The study then illustrates the two-stage methodology utilized, which separates the effect of time-variant and time-invariant explanatory variables on efficiency. A following section presents the results obtained. After performing some sensitivity checks, conclusions are provided in a final section.

2. Overview of Brazil's water and sewerage (WS) industry

In 1971, Brazil created a national plan for WS provision (PLANASA).[5] This plan delegated authority for the provision of WS services to twenty seven newly born state-owned companies. According to PLANASA, these public companies were the only sanitation entities authorized to obtain financing from the National Housing Bank (Banco Nacional de Habitaçao - BNH). This feature made PLANASA attractive for the municipalities that were interested in expanding their sanitation systems.[6] About 3,200 municipalities joined the new plan, awarding concessions to the state-owned companies for 20 to 30 years.[7] On the other hand, about 1,800 municipalities never adhered to PLANASA, providing WS services on their own ever since. The three types of local operators of this paper (Private, Public-Corporative and Public-Non-Corporative) provide WS services within the municipalities that never joined the system.

The PLANASA model started to decline in the 80's. After 1986, the BNH was unable to finance the required expansion of the WS sector due to a weak fiscal situation of the

while in a later study Estache and Rossi (2002) found no difference. For Africa, Estache and Kouassi (2002) found evidence in favor of private firms.

5 Plano Nacional de Saneamento. See Soares (2001) for a detailed description.

6 See Faria (2005).

7 In many cases, however, there was never any formal contract between the municipality and the state-owned companies.

federal government.[8] Anti-inflationary policies may have also played a role, since the government at that time pressed for low water tariffs to keep inflation under control. The 80's decade was also characterized by an emphasis on decentralization, best illustrated in the constitutional reform of 1988. The centralizing concept of PLANASA, on the other hand, was more in accordance to the military regimes of earlier decades.

There have recently been some attempts to define a new framework for the Brazilian WS sector. [9] Bill 4147/2001, for example, intended to allow for more private participation. This bill defined the states to be the conceding authority in metropolitan areas. However, the constitutional reform of 1988 granted to municipalities the right to make concessions for public services of "local" interest.[10] Due to that controversy about the interpretation of the Constitution, Bill 4147 never became law.[11]

A new Bill 5296/2005 also attempted to redefine the rules for the WS sector. A Parliamentary Commission approved it on July 2006 after many modifications and it recently became Law 11445 in January 2007. This new bill specifies that municipalities have the conceding authority over services of local interest. The implications of the new Law 11445 are yet to be seen.

Due to the heated debate about where the conceding authority resides, only some municipalities that never adhered to PLANASA have made concessions to private

[8] PLANASA formally extinguished in 1992. See Parlatore (1999).

[9] A Nacional Water Agency (Agencia Nacional de Aguas – ANA) was created in 2000. However, the main function of ANA is to monitor the utilization of water resources. Its role as a regulator is yet to be defined.

[10] Water distribution and sewerage collection are defined as services of "local" interest. On the other hand, water catchment and water and sewerage treatment are defined to be of local interest only in case of exclusive use by the municipality. See Ministério das Cidades, http://www.cidades.gov.br (last visit: March 26, 2007).

[11] There was also a strong opposition from the public and representative institutions, like the Brazilian Association of Sanitary and Environmental Engineering (Associação Brasileira de Engenharia Sanitária e Ambiental – ABES). See http://www.abes-dn.org.br (last visit: March 26, 2007).

operators.[12] These private companies provide WS services to less than 4% of the population.[13] The Brazilian Association of Private Water and Sewage Operators (ABCON) suggests that only through a more active private participation will the WS sector meet the high investment levels required.[14]

According to 2004 data, approximately 112,000 people are directly employed in the WS sector, almost 90% by the state-owned companies. The national coverage for water services is roughly 85%, although the sewerage coverage is below 60%. On average, almost 30% of the treated water produced is unaccounted for, due to leaking through broken pipes and illegal connections. Furthermore, only 50% of the sewerage volume collected receives some type of treatment. Table 1 shows these statistics by operator-type.

3. Methodology

Duality theory implies that the production technology of a firm can be modeled with a cost function, where the firm's cost depends on its output level and the prices of the inputs employed in production. Other factors may also affect the firm's technology and hence the firm's costs. Specifically:

$$c = c(q, w, z), \qquad (1)$$

where c denotes cost, q denotes output level, w denotes input prices and z includes other control variables.[15] To empirically estimate (1), a panel data framework is adopted:

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[12] See Vargas and De Lima (2004).

[13] This figure contrasts with the situation in other infrastructure sectors like telecommunications, railroads and electricity, where private participation is much more active. See Oliveira and Fujiwara (2005) and Pinheiro (2003).

[14] Associação Brasileira de Concessionárias de Serviços Públicos de Água e Esgoto. See http://www.abcon.com.br (last visit: March 26, 2007).

[15] Control variables have been sometimes denominated *hedonic* measures, referring to the approach introduced by Spady and Friedlaender (1978) for the trucking industry. These authors emphasize that the service dimensions provided by the firm should enter the cost function as explanatory variables. Feigenbaum and Teeples (1983) first introduced the hedonic approach to the water sector.

$$Y_{it} = X_{it}^{'}\beta + u_i + \varepsilon_{it} , \qquad (2)$$

where Y_{it} denotes the dependent variable for individual *i* at time *t*, X_{it} denotes the vector of explanatory variables for individual *i* at time *t*, u_i accounts for time-invariant heterogeneity at the individual level and ε_{it} denotes random statistical noise. Heterogeneity is the denomination of the observed and unobserved unique individual characteristics.

Fixed or random effects models can be adopted for panel data. The fixed effects model allows unobserved heterogeneity to be correlated with the explanatory variables. In contrast, the random effects model assumes that any unobserved heterogeneity is distributed independently of the covariates. In the context of this study, correlation between unobserved heterogeneity and the explanatory variables is hard to rule out. Such a correlation would exist, for example, if the firm can modify its output level based on private information about its unobserved inefficiency. Therefore, a fixed effects model for panel data is employed.[16] The fixed effects formulation allows the unobserved inefficiency to be captured by the firm-specific coefficients.[17] Within the panel data framework described, the cost function from (1) takes the following form:

$$c_{it} = \beta_0 + \beta_q q_{it} + \beta_w w_{it} + \beta_z z_{it} + \varepsilon_{it} + u_i , \qquad (3)$$

where the *β's* are parameters to be estimated and u_i denotes firm-specific cost inefficiency and any additional unobserved heterogeneity. It is assumed that the ε_{it}'s are i.i.d and uncorrelated with the covariates. In contrast, the u_i's are allowed to be potentially

16 A Hausman test is performed in the Appendix to formally support the decision of fixed effects over random effects.

17 According to Greene (2005), assuming that inefficiency is time-invariant is not a problem in short panels. This is especially true in the water industry, which is characterized by low technological change.

correlated with the explanatory variables.[18] The least-squares dummy variables (LSDV) estimator is utilized, including also a year-specific effect:[19]

$$c_{it} = \alpha_i + \beta_q q_{it} + \beta_w w_{it} + \beta_z z_{it} + \gamma_t + \varepsilon_{it}\,, \tag{4}$$

where the firm-specific intercepts $\alpha_i \equiv \beta_0 + u_i$ account for cost inefficiency and any other unobserved heterogeneity. Utilizing this formulation, Schmidt and Sickles (1984) proposed the measure $\alpha_i^* = \alpha_i - \min(\alpha_i)$ to construct a ranking of relative inefficiency. Their approach permits the computation of individual inefficiency terms relative to the most efficient firm in the sample.[20] That calculation might be appropriate when one is concerned about efficiency at the individual-firm level. For example, a regulator could set the tariff of firm "A" based partly on its relative efficiency with respect to firm "B", as suggested by Shleifer (1985). However, the focus of this study is not yardstick comparison between individual operators but rather between different types of firms. The goal of this paper is to identify whether Regional, Private or Public firms (Corporative and Non-Corporative) are relatively more efficient in providing WS services in Brazil. Thus, an alternative analysis is pursued.

After estimating (4), the predicted firm-specific costs $\hat{\alpha}_i$ are computed. Once these firm-specific costs $\hat{\alpha}_i$ are obtained, an additional regression is performed. This new regression isolates the effect of time-invariant characteristics (e.g., type) on each firm's

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18 It is unnecessary to make any distributional assumption on the inefficiency term μ_i. If one is willing to make distributional assumptions on the μ_i, Maximum Likelihood would theoretically allow for more efficient estimates than both fixed and random effects models. Nevertheless, Kumbhakar and Lovell (2000) and Murillo-Zamorano (2004) mention several papers that after performing empirical comparisons of the three approaches generate similar efficiency rankings, especially at the top and bottom of the distribution.

19 The LSDV estimator is equivalent to the within-groups estimator.

20 Ashton (2000) constructs an efficiency ranking of British water firms utilizing that measure.

efficiency (which is also time-invariant). Specifically, the dependent variable in the second-stage regression is the predicted firm-specific cost $\hat{\alpha}_i$, while firm-type and location dummies are the time-invariant explanatory variables. Dummies for location are included because geographic heterogeneity may have an effect on the availability (hence, its cost) of raw water. Since the type and location of each firm do not vary over the time period analyzed, their impact on cost efficiency is isolated by means of a separate regression.

Although output is present as a covariate in the first-stage regression, the firm-specific costs may still be correlated with output by the nature of the fixed effects model. Recall that a fixed effects model allows for correlation between the explanatory variables (for example, output) and any unobserved heterogeneity (which is captured by the firm-specific intercept $\hat{\alpha}_i$). Therefore, the firm-specific costs are normalized per unit of output when playing the role of the dependent variable in the additional regression. The second-stage regression takes then the following form:

$$\frac{\hat{\alpha}_i}{\bar{q}_i} = \lambda + \delta * Type_i + \chi * Location_i + \zeta_i \tag{5}$$

The vectors δ and χ contain the coefficients for each of the *Type* and *Location* indicator variables. Meanwhile, $\bar{q}_i$ represents the average output of firm *i* for the period under analysis, which is utilized for the normalization of firm-specific costs. In the second-stage regression (5), interest resides on the coefficients of the firm-type indicators. If the coefficients in δ for the firm-type dummy variables are statistically significant, there will be evidence of relatively distinct firm-specific costs (per unit of output) between the different types of operator.

Following the extant literature, *Operating Cost* is utilized to represent the dependent variable *c* in (4).[21] *Wage* is employed to represent input prices *w*, since they account for more than 40% of the operating cost.[22] Wages were calculated as the ratio of total labor expenses divided by the number of employees, as it is standard in the literature.[23]

Although the volume of water produced seems like the most appealing output variable, the number of connections has also been widely used by researchers.[24] Thus, both *Volume* and *Connections* are employed as two alternative measures of output *q*. As control variables to be included in *z*, this study utilizes *Network Length*,[25] the *Percentage of Urban Population*,[26] a *Metering Index,*[27] a *Fluorination Index*[28] and a *Sewerage Dummy*[29] that

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21 Although it is also conceivable to use total cost as the dependent variable, that would require data on the price of capital, since depreciation charges constitute a large share of total costs. Since reliable data on the price of capital are unavailable, this study focuses only on operating cost, which excludes depreciation.

22 Data on other input prices are limited. Some data on energy consumption suggests that energy is the second most important input, representing around 20% of operating cost.

23 More detailed data on input prices would theoretically allow for more efficient estimates utilizing the Seemingly Unrelated Regressions (SUR) model proposed by Zellner (1962). This model consists of a multivariate regression system. Besides the cost function, the input-demand share-equations are utilized, enhancing the efficiency of the estimation because the same coefficients participate not only in the cost function but also in the input-demand share-equations.

24 The number of connections is employed by Ashton (2000), Estache and Rossi (1999), Estache and Rossi (2002) and Teeples and Glyer (1987). The volume of water produced is utilized by Antonioli and Filippini (2001), Aubert and Reynaud (2005), Bhattacharyya, Harris et al. (1995), Bhattacharyya, Parker and Raffiee (1994), Bottaso and Conti (2003), Corton (2003), Crain and Zardkoohi (1978), Cubbin and Tzanidakis (1998), Estache and Rossi (1999), Estache and Rossi (2002), Fabbri and Fraquelli (2000), Fox and Hofler (1986), Kim (1987), Stewart (1993) and Teeples and Glyer (1987). The number of customers is used by Antonioli and Filippini (2001), Aubert and Reynaud (2005), Fabbri and Fraquelli (2000) and Saal and Parker (2000).

25 The length of pipes is utilized by Antonioli and Filippini (2001), Bottaso and Conti (2003), Corton (2003), Cubbin and Tzanidakis (1998), Fox and Hofler (1986), Kim (1987) and Stewart (1993).

26 A proxy of density is used by Bottaso and Conti (2003), Fabbri and Fraquelli (2000) (ratio between population served and the length of pipelines) and Teeples and Glyer (1987) (connections per mile of line). The percentage of non-domestic consumers is employed by Bottaso and Conti (2003), Estache and Rossi (1999), Estache and Rossi (2002), Fox and Hofler (1986), Kim (1987) and Stewart (1993).

27 The percentage of metered connections is used by Cubbin and Tzanidakis (1998), Estache and Rossi (2002), Feigenbaum and Teeples (1983) and Teeples and Glyer (1987).

28 A proxy for quality is used by Antonioli and Filippini (2001) (dummy indicating if water has to be chemically treated before distribution), Estache and Rossi (1999) (continuity), Estache and Rossi (2002) (continuity), Feigenbaum, and Teeples (1983) (water treatment index), Fox and Hofler (1986) (tests of

equals 1 if the firm also provides sewerage collection (not all operators provide both services).[30]

Earlier literature suggests that a longer network should be associated with higher costs due to its maintenance (fixing leaks, for example). Previous research also suggests that a higher metering index should be associated with higher costs due to the reading and maintenance of the meters. The fluorination index should also be associated with higher costs due to a more intense chemical treatment of water before delivery. The sewerage dummy is also expected to show a positive sign, capturing the higher operating cost of providing both water and sewerage services. Finally, the effect of a higher proportion of urban population in the area served is difficult to predict. On the one hand, many researchers argue that having customers densely located in a small area reduces costs. On the other hand, Feigenbaum and Teeples (1983) argue that “we should expect that it is more

water quality and tests of organic contamination), Saal and Parker (2000) (percentage of water that is compliant with key parameters relative to the compliance percentage for England and Wales) and Teeples and Glyer (1987) (water treatment index).

[29] The *Sewerage Dummy* participates in the first-stage regression rather than in the second-stage regression because it is time-variant for a few operators that start providing sewerage services within the period analyzed.

[30] Other control variables have been also employed in previous literature. The percentage of water losses is used by Antonioli and Filippini (2001) and Bhattacharyya, Harris et al. (1995). The storage capacity is used by Feigenbaum and Teeples (1983), Fox and Hofler (1986) and Teeples and Glyer (1987). A dummy indicating if the utility has to purchase water from other utility is employed by Aubert and Reynaud (2005), Feigenbaum and Teeples (1983), Fox and Hofler (1986) and Teeples and Glyer (1987) (they use the proportion of water that is purchased). The number of districts served is used by Corton (2003). A dummy indicating if the utility obtains water from surface sources is used by Aubert and Reynaud (2005), Bhattacharyya, Harris et al. (1995), Bottaso and Conti (2003) (they use river sources), Estache and Rossi (1999) and Fox and Hofler (1986). I ignore the reasons that support the inclusion of a proxy for capital stock, as done by Antonioli and Filippini (2001) (number of water wells), Aubert and Reynaud (2005) (average net base rate divided by the estimated price of capital), Bhattacharyya, Harris et al. (1995) (residual of the revenue less variable costs) and Bottaso and Conti (2003) (replacement costs of net tangible assets). Such a variable would be an appropriate covariate in a production function, but not in a cost function

costly to supply more densely developed service areas, which requires more hydrants, higher water pressure and greater peak capabilities for fire protection."[31]

The main source of data is the National System of Sanitation Information (SNIS) of Brazil.[32] Operators voluntarily join the SNIS, which started collecting data in 1995. The number of firms providing data has increased each year ever since. This study utilizes an unbalanced panel for 2000-2004. There are approximately 180 observations for 2000 and 340 observations for 2004, with almost 1200 observations in total.[33] The SNIS is part of the Modernization Program of the Sanitation Sector (PMSS), which Brazil started in 1992 with financial support from the World Bank.[34]

4. Results

Summary statistics of the variables used in the first-stage LSDV regressions are presented in Table 2, discriminated by operator type. The size difference between the Regional and Local operators is evident when observing the average output, network length and operating cost of each type of firm. For example, from the point of view of the number of connections, the average Regional operator is almost 14 times bigger than the average Public-Corporative provider (1,021,909 and 74,573 connections, respectively).

Table 3 presents the results from both LSDV regressions. Alternatively, both *Connections* and *Volume* are positive and statistically significant. The hypotheses that their

[31] Feigenbaum and Teeples (1983, p.674). They confirm that result in their paper.

[32] Sistema Nacional de Informaçoes sobre Saneamento. See www.snis.gov.br (last visit: May 7, 2007).

[33] Missing data on some variables explain the variation in the number of observations across the two models presented in the next section. The online data are split into several files, each containing only a certain type of variables (financial, descriptive, operational, etc) and a certain type of firm (regional, local, etc). These spreadsheets were pooled together for this work.

[34] Programa de Modernizaçao do Setor de Saneamento. The PMSS resides on the sphere of the National Secretariat of Environmental Sanitation (Secretaria Nacional de Saneamento Ambiental), which depends on the Ministry of Cities (Ministério das Cidades). See www.cidades.gov.br (last visit: May 7, 2007).

coefficients are equal to 1 are rejected, which provides evidence of increasing returns to scale regardless of the output measure chosen. For example, a 10% increase in the volume of water produced generates only a 0.98% increase in operating cost.[35] This confirms the argument made by AESBE, which favors state-level provision of water services due to economies of scale. As expected, *Wage* also has a positive and statistically significant effect on cost in both specifications.

From the set of control variables, the *Metering Index* shows the expected positive sign and statistical significance in both specifications. This means that when the fraction of metered connections is higher, operating cost increases. This is in line with earlier research suggesting that reading and maintaining the meters has a positive impact on cost. The *Sewerage Dummy* coefficient is positive and statistically significant in both regressions. This means that collecting and treating sewage increases the operating cost of a water provider. Finally, *Network Length*, the *Percentage of Urban Population* and the *Fluorination Index* are statistically insignificant.

The first-stage LSDV regressions in Table 3 also illustrate that output, input prices and other technological factors explain most of the variation of operating cost.[36] As a result, the firm-specific costs provided by the first-stage regressions represent a very small portion of the operating cost (less than 1% on average).

After running the first-stage LSDV regressions, the predicted firm-specific costs $\hat{\alpha}_i$ are obtained. Following (5), a second-stage regression is later performed, where the firm-

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[35] To test for economies of scale that may vary with output, specifications including the square of the output variable were run. The results were not satisfactory. The $Volume^2$ variable was not statistically significant, while *Volume* remained statistically significant with little change in the value of its coefficient. Meanwhile, both *Connections* and $Connections^2$ became statistically insignificant.

[36] The high explanatory power of both models remains even if the firm fixed effects (not reported) are excluded. In that case, the R^2 is still above 0.95.

specific cost (per unit of output) plays the role of the dependent variable. Firm-type and five location-indicators are the time-invariant explanatory variables in the second-stage regression. Dummies for the five different regions in which Brazil is divided are included because geographic heterogeneity may differently affect the cost of access to raw water.[37] Even when the specific effect of geographic heterogeneity is not the focus of this study, it is important to control for that time-invariant characteristic. If the firm-type dummy variables are statistically significant in the second-stage regression, there will be evidence of relatively distinct firm-specific costs between the different types of operators.

Table 4 presents the results of the second-stage regression. The *Regional* dummy has the largest negative and statistically significant coefficient (-1.486 and -0.563, using *Connections* and *Volume* as the output measure, respectively). This indicates that the Regional state-owned firms have the lowest firm-specific cost (per unit of output) of the sample. At the local level, meanwhile, the cost efficiency comparison between private and public operators depends on how the public provider is organized. The negative and statistically significant coefficients of both the *Private* (-0.331 and -0.294, respectively) and the *Public-Corp* (-0.341 and -0.367) variables illustrate that these operators have lower firm-specific costs than the *Public-Non-Corp* category (the type omitted in Table 4). A test also shows that there is no statistically significant difference between the firm-specific cost of Private and Public-Corporative operators.

Table 5 illustrates the value of the firm-specific costs obtained from the results of the second-stage regression. The table shows that the Regional state-owned operators are the lowest-cost WS providers, while the local Public-Non-Corporative operators are the

[37] These location dummies could partially capture different energy prices as well.

highest-cost WS providers in Brazil. Although the differences presented in Table 5 are substantial and statistically significant, it is worth recalling that the firm-specific costs are not a significant portion of the operating costs.

5. Sensitivity Checks

As a first sensitivity check, a balanced panel was used. Since the sample size increases over the years, it is important to check that incorporating new firms does not affect the analysis. The first-stage results are presented in Table 6. The positive and significant effect of both output variables (*Connections* and *Volume*) remains. The same is true for the *Wage* variable across both specifications. Table 7 contains the results of the second-stage regressions. It can be verified that the lowest firm-specific cost for the Regional type is confirmed when using a balanced panel, regardless of the output variable chosen. However, the lower firm-specific costs for the Public-Corporative and Private type are not replicated when a balanced panel is employed. The reason behind this statistically imprecise result could be the loss of observations when utilizing a balanced panel. That is, most of the observations dropped when using a balanced panel correspond to local firms.

As a second sensitivity check, and utilizing again the large unbalanced panel, the Regional type was excluded from the sample. The reason for this sensitivity check is that the size differential between the Regional and Local operators could affect the conclusions. Table 8 shows the results of the first-stage LSDV regressions and Table 9 contains the results of the second-stage regressions. The first-stage regressions indicate that the positive and statistically significant effect of output, wage and the metering variable are again verified, along with the sewerage dummy. Furthermore, the coefficients obtained are similar to those in Table 3 and Table 4. For example, the measure of economies of scale excluding the Regional type suggests that a 10% increase in the volume of water produced generates a 0.94% increase in operating cost. The second-stage regressions show that the higher firm-specific cost for the Public-Non-Corporative type (the omitted category in Table 9) is again confirmed, providing confidence about the conclusions drawn earlier. The statistically insignificant difference between the Private and Public-Corporative operators is also verified in the second-stage regressions.

6. Conclusions

Brazil is a country that lacks perfect access to WS services. Efficiency improvements could free up funds for network expansion, which would constitute a step towards a desired full service situation. Therefore, greater attention for cost-containment is needed, regardless of the jurisdictional and ownership/organizational status of the WS operators. Improving our understanding of relative performance can help policy makers focus on the sources of differential cost patterns.

The results of this study suggest that, at least for Brazil, evidence of economies of scale is enough to claim that WS provision at the state level is more efficient than WS provision at the municipal level. Economies of scale generate substantial cost savings, which far outweigh any potential differential in firm-specific costs. As such, the argument made by AESBE (favoring WS provision at the state-level) seems more compelling than the argument made by ASSEMAE (favoring WS provision at the municipal-level).

In addition to economies of scale, this study finds evidence of inherently lower firm-specific costs (per unit of output) for Regional state-owned firms than for all other types of WS operators in Brazil. These lower costs slightly reinforce the efficiency gains the Regional firms achieve through actual economies of scale. Finally, at the local level, this study also shows evidence of higher firm-specific costs (per unit of output) for Public-Non-Corporative providers than for Private and Public-Corporative providers. Future research could examine what features generate the intrinsic cost differences among operator types. In particular, the higher firm-specific cost for the Public-Non-Corporative type deserves further attention. It may be important to check whether the not-for-profit motive of those organizations actually drives their higher firm-specific costs.

Even when cost differences between the different types of WS operators were found, it is worth noting that these differences represent a small portion of operating costs. The first-stage regressions illustrated that output, input prices and other technological factors explain most of the variation of operating cost, regardless of the firm-type. As a result, the firm-specific cost differences presented are significant from a statistical point of view, but less significant from an economic perspective.

Clearly, much work remains. For the purpose of rewarding good performance and penalizing weak performance, scholars and practitioners need to develop efficiency-measuring procedures that can pass legal challenges. The process must continue to build on the pioneering research of those whose work is cited in the references. In particular, the publication of league tables is one way to put pressure on the weakest performing WS utilities. Similarly, the managers of WS utilities in the top 20 percent might be awarded some share of the cost savings that can be attributed to their efforts. Those promoting improvements in WS sector performance can take steps to reduce production costs and free up cash flows for network rehabilitation and expansion. Identifying, implementing, and evaluating good incentive systems represent a challenge for regulators.

A final issue that also deserves future research follows. The analysis in this paper only considered relative measures of efficiency. The goal was to identify sources of cost differences between the different types of operators. However, cost savings for the entire industry could also be estimated. For example, reducing water losses would also free up funds for network expansion. Table 1 shows that water losses in 2004 stood at almost 30% on average, while they were 49% for the state-owned operators. This would suggest that a reduction of water losses by 10% should not be hard to achieve. Yet, it could represent an almost 1% lower operating cost. Garcia and Thomas (2001), for example, suggest that a plausible explanation behind the lack of incentives for reducing water losses is that it may be cheaper to produce more water instead. Although geography might validate this statement in some cases, the issue definitely deserves further exploration.

Table 1. Average statistics by operator-type for 2004[38]

Type of firm	#	Connections	Employees	Water cover.	Sewer. cover.	Water losses	Sewer. Treatm.
Private	31	30470	88.9	80.1%	50.4%	29.1%	54.4%
Public-Non-Corp	296	18851	99.2	86.3%	63.0%	26.6%	46.5%
Public-Corp	11	75180	400.3	98.8%	68.5%	41.3%	36.6%
Regional	25	1104748	2978.6	71.3%	33.8%	48.7%	74.5%
Total	369	91660	300.7	85.1%	58.5%	28.9%	51.3%

[38] The sample also includes six Microregional operators, which are not the focus of the analysis. These are public operators that are neither Regional nor Local, since they provide services to just a few municipalities.

Table 2. Summary statistics for first-stage regressions[39]

Variable	Private N=62	Public-Non-Corp. N=913	Public-Corp. N=42	Regional N=121
Operating Cost	11,450,480 (16,243,170)	6,237,776 (16,087,230)	31,389,410 (43,045,090)	291,421,800 (424,122,100)
Connections	50,539 (67,902)	24,251 (39,282)	74,573 (67,960)	1,021,909 (1,234,135)
Volume	22,239 (41,240)	8,552 (17,315)	34,899 (33,649)	396,122 (583,563)
Wage	20,148 (8,978)	14,334 (7,841)	22,081 (11,865)	37,542 (14,028)
Network Length	642 (840)	294 (457)	1,005 (1,044)	11,398 (12,930)
Dummy sewerage	0.82 (0.39)	0.56 (0.50)	0.98 (0.15)	0.94 (0.23)
Urban %	0.88 (0.09)	0.77 (0.21)	0.95 (0.05)	0.77 (0.12)
Metering %	0.88 (0.19)	0.77 (0.32)	0.86 (0.21)	0.74 (0.28)
Fluorination %	0.33 (0.46)	0.30 (0.44)	0.35 (0.47)	0.20 (0.36)

N=1163
(Standard deviations in parenthesis)

39 Volume is in 1000m^3/year and Network Length is in Km. Operating Cost and Wage are expressed in nominal Reais/year (a referee correctly pointed out that it is not necessary to adjust monetary figures for inflation). The 1163 observations include 25 observations for the Microregional category, which are not reported. For the Volume variable, summary statistics are for 1172 observations.

Table 3. First-stage LSDV regression results[40]

Dependent Variable: Operating Cost	Connections	Volume
Connections	0.427 (0.112)***	
Volume		0.098 (0.040)**
Wage	0.150 (0.043)***	0.157 (0.040)***
Network Length	0.024 (0.073)	0.089 (0.088)
Dummy sewerage	0.122 (0.058)**	0.138 (0.067)**
Urban %	0.070 (0.246)	0.082 (0.258)
Metering %	0.382 (0.177)**	0.409 (0.165)**
Fluorination %	0.001 (0.035)	0.005 (0.035)
Constant	8.496 (1.133)***	11.274 (0.713)***
Observations	1163	1172
R-squared	0.99730	0.99729

Year and firm fixed effects not reported
Standard errors clustered at the state-level
* significant at 10% - ** significant at 5% - *** significant at 1%

[40] Operating Cost, Volume, Connections, Wage and Network length are in *ln* form. The statistical significance of all coefficients is very similar when the standard errors are clustered at the region level.

Table 4. Second-stage regression results

Dependent Variable: (ln) Firm-Specific Cost per Unit of Output (from LSDV regressions)	Connections	Volume
Private	-0.331	-0.294
	(0.127)***	(0.124)**
Public-Corp	-0.341	-0.367
	(0.183)*	(0.148)**
Regional	-1.486	-0.563
	(0.144)***	(0.111)***
Constant	-0.801	3.297
	(0.049)***	(0.092)***
Observations	380	380
R-squared	0.31726	0.04428

Omitted type: Public-Non-Corporative
Region fixed effects not reported
Robust standard errors in parenthesis
* significant at 10% - ** significant at 5% - *** significant at 1%

Table 5. Ranking of firm-specific costs across firm-types

Firm type	Firm-Specific cost per unit of output		Index (Regional=100)	
	(\$/Connection)	(\$/1000m^3)		
Regional	0.12	10.70	100	100
Public-Corp	0.38	13.03	314	122
Private	0.38	14.01	317	131
Public-Non-Corp	0.53	18.80	441	176

Table 6. First-stage LSDV regression results using a balanced panel

Dependent Variable: Operating Cost	Connections	Volume
Connections	0.631 (0.152)***	
Volume		0.127 (0.043)***
Wage	0.185 (0.022)***	0.186 (0.026)***
Network Length	0.014 (0.074)	0.082 (0.104)
Dummy sewerage	0.034 (0.048)	0.046 (0.045)
Urban %	-0.158 (0.135)	-0.150 (0.139)
Metering %	-0.002 (0.203)	-0.009 (0.188)
Fluorination %	0.023 (0.028)	0.023 (0.030)
Constant	7.894 (1.155)***	13.287 (1.053)***
Observations	758	766
R-squared	0.99713	0.99711

Year and firm fixed effects not reported
Standard errors clustered at the state-level
* significant at 10% - ** significant at 5% - *** significant at 1%

Table 7. Second-stage regression results using a balanced panel

Dependent Variable: (ln) Firm-Specific Cost per Unit of Output (from LSDV regressions)	Connections	Volume
Private	-0.176	-0.265
	(0.219)	(0.179)
Public-Corp	-0.181	-0.209
	(0.232)	(0.173)
Regional	-2.142	-0.604
	(0.171)***	(0.116)***
Constant	-3.041	3.154
	(0.086)***	(0.165)***
Observations	170	170
R-squared	0.54194	0.11137

Omitted type: Public-Non-Corporative
Region fixed effects not reported
Robust standard errors in parenthesis
* significant at 10% - ** significant at 5% - *** significant at 1%

Table 8. First-stage LSDV regression results excluding the Regional type

Dependent Variable: Operating Cost	Connections	Volume
Connections	0.439 (0.130)***	
Volume		0.094 (0.040)**
Wage	0.145 (0.045)***	0.152 (0.041)***
Network Length	0.022 (0.072)	0.083 (0.087)
Dummy sewerage	0.119 (0.058)*	0.135 (0.066)*
Urban %	0.062 (0.252)	0.077 (0.264)
Metering %	0.424 (0.194)**	0.460 (0.179)**
Fluorination %	0.004 (0.039)	0.005 (0.039)
Constant	8.433 (1.326)***	11.37 (0.721)***
Observations	1042	1047
R-squared	0.99579	0.99575

Year and firm fixed effects not reported
Standard errors clustered at the state-level
* significant at 10% - ** significant at 5% - *** significant at 1%

Table 9. Second-stage regression results excluding the Regional type

Dependent Variable: (ln) Firm-Specific Cost per Unit of Output (from LSDV regressions)	Connections	Volume
Private	-0.331	-0.286
	(0.127)***	(0.120)**
Public-Corp	-0.367	-0.363
	(0.187)*	(0.145)**
Constant	-1.186	3.090
	(0.050)***	(0.094)***
Observations	354	354
R-squared	0.1322	0.01567

Omitted type: Public-Non-Corporative
Region fixed effects not reported
Robust standard errors in parenthesis
* significant at 10% - ** significant at 5% - *** significant at 1%

Appendix – Hausman test

To formally rely on fixed effects rather than on random effects estimation, a Hausman test is performed. The Hausman test checks a more efficient model (random effects) against a less efficient but consistent model (fixed effects). This procedure could guarantee that the more efficient model (random effects) also provides consistent results. The null hypothesis behind the Hausman test is that the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator.

Utilizing *Volume* as the output measure, the coefficients obtained with fixed and random effects estimations and the corresponding differences between them are as follows:

	Coefficients			
Variable	Fixed Effects	Random Effects	Differ.	Std. Error
Volume	0.098	0.313	-0.215	0.034
Wage	0.157	0.229	-0.072	0.033
Network Length	0.089	0.582	-0.494	0.083
Dummy sewerage	0.138	0.153	-0.015	0.046
Urban %	0.082	0.320	-0.238	0.242
Metering %	0.409	0.366	0.043	0.151
Fluorination %	0.005	0.070	-0.065	0.026

The resulting $\chi^2_{(7)}$ value is 142.35, which implies a p-value that converges to zero. Therefore, the Hausman test provides enough evidence to reject the null hypothesis of random effects.

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