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Private or Public Enterprises? Cost Inefficiency Limits - An Application to Water Supply Companies in Brazil

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Abstract

In this paper we analyze the cost inefficiency limits of firms operated by the government. First, we prove, through a simple theoretical model, the existence of a limit of the cost inefficiency that a public firm may have. Such limit depends on the market demand and cost structure. Above that limit, transferring the firm's operations to a private initiative is better. Second, using data from the Sanitation Information System of Brazil, we propose an empirical procedure based on the Laffont and Tirole (1986) model of firms regulation to measure the cost inefficiency of public water providers in Brazil.

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1 Introduction

In choosing the type of firm, either public or private, that must serve a sector in the economy it is important to take into consideration the social benefits of each alternative. The private firm, being a monopolist, or another class of imperfect competitor, will bring with its supply a deadweight loss that is inefficient for the society. On the other hand, the public firm, even though its objective should be consumers' welfare, may face additional problems (lack of incentives from management, discontinuity in the party that is in charge of government, insufficient investment, among others); these also prevent it from achieving the final goal.

If the private firm model is chosen, the regulation of the firm arises as a helpful tool to recover (at least in the second best level) efficiency. However, due to national security reasons, high inelasticity of essential services (like water) or lack of investments in some sectors, many economies opt for the presence of public firms in some markets.

In the literature, we can find numerous studies about those issues. The classical textbook with a deep analysis of regulation that have to be considered is Laffont and Tirole (1993). In Viscusi et al. (2005), the justification for regulation are presented and in particular, the regulation of natural monopolies, comparing the managerial models of private and public enterprises. Finally, Joskow (2007), provides an overview of the theoretical and empirical literature on the regulation of natural monopolies. We can find one of the pioneer works on monopoly regulation in Baron

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and Myerson (1982), where it is analyzed the regulation of a monopolistic firm whose costs are unknown. Typically, the regulator maximizes a social welfare function and the optimal regulatory policy, prices and subsidies are designed as functions of the costs reported by the firms. Despite regulation appearing as a good alternative for recovering efficiency, some works highlighted that it may present some difficulties. Pint (1991) compares the effects of government ownership and regulation under private ownership on the production decisions of a monopoly firm. The privately-owned regulated firm will use relatively more capital, while the publicly-owned firm will use relatively more labor than the second-best efficient solution. An empirical study by Mountain (2014) reports that for electricity distribution in Australia, ownership matters for regulatory independence. Additionally, the implementation of a price cap regulation for government-owned NSPs (network services providers) was not as successful as it was for privately owned NSPs. We also have the work of Bougheas and Worrall (2012), who showed the effects of a regulated monopoly that pads its costs to increase cost reimbursement from the regulator.

Since public enterprises, even those operating under regulation, are not satisfactory, privatization arises as an alternative for the economy. Bös (1991) presents a theoretical discussion on the forms and arguments both for and against privatization. The author analyzes whether full privatization coupled with subsequent regulation is better than partial privatization with the government regulating from within the firm. In this regard, Anderson et al. (1997) proved that when a public firm that is competing with private ones becomes private, the short-run effect is harmful; however, with free entrance, the effect is beneficial in the long-run. They also suggested that profitable firms should not necessarily be privatized. David and Chiang (2009) assess the productive and strategic advantages in alternative organizational configurations: pure public, pure private, and public-private mix. When applied to the provision of Emergency Medical Services in the U.S., they found that smaller cities and less access to hospitals favored the mixed public-private configuration. More recently, Fujiwara (2007) and Wang and Chiou (2018) analyzed the effects of privatization in mixed oligopolies and their welfare consequences. In the former, it is proven that the optimal level of partial privatization depends on the consumers' preferences for variety. In the latter, conditions are provided to obtain an optimal decision on the degree of privatization, either full privatization or full nationalization.

This papers contributes to the discussions above by analyzing the level of tolerance for choosing of a public enterprise rather than a private one to serve a specific market. Namely, we depart from a model of a public firm serving the consumers, having social welfare as an objective function, but inflating its total cost by a factor λ. If that factor is high enough, it will be socially better to privatize the firm. So, we will find the maximum value for that factor that allows the public to be the best choice for the society. We also provide a methodology to measure the size of the inefficiency of firms in a sector. Specifically, we perform an empirical application using data from the National Sanitation Information System of Brazil regarding the enterprises of water and sewer services in the Brazilian Municipalities. As a result, we are able to detect if the public-managed firms are the most cost inefficient measuring their level of inefficiency. Using several estimations of price-elasticity of water demand given in the literature, we show that such cost inefficiency is tolerated due to the low elasticity of demand in that market.

The paper is divided into five sections. After this introductory section, in Section 2 we present a simple theoretical model to show the existence of a limit for the cost inefficiency of a public firm, above which it is socially better to privatize it. In Section 3 we briefly present Laffont and Tirole (1986) model of firm regulation based on the firm's cost information; this is in order to present the theoretical model we are going to use in our empirical exercise. In Section 4 we perform our empirical analysis to the water and sewer services in Brazil and we show how the government-managed firms are more cost inefficient and the size of such inefficiency. Finally, in Section 5 we summarize the main findings of our work.

2 A limit for the public monopoly cost inefficiency

In this section, we provide an upper limit for the cost inefficiency that a monopolistic firm managed by the government can have. Beyond that level of inefficiency, it will be better to leave the control of the firm to the private initiative.

The elements of the model are the following. A good is provided by a single firm which can be controlled by the government (public monopoly) or by a private monopoly. There is a representative consumer with utility function $u(q,m) = \phi(q) + m$, where $q \geq 0$ is the amount of the good consumed and $m \in \mathbb{R}$ is the expenditure in all other goods and services. The firm has a cost function $c(q)$, and when it is operated by the government it increases by a factor $(1+\lambda)$, where $\lambda \geq 0$; thus, the cost of the public monopoly is given by $(1+\lambda)c(q)$. We will assume the following hypothesis for the functions above.

Hypothesis 1. *The utility and cost functions satisfy the following conditions:*

$$\phi' > 0, \;\; \phi'' < 0, \;\; \phi'(0) = +\infty, \;\; \phi'(+\infty) = 0;$$

$$c' > 0, \;\; c'' > 0, \;\; c'(0) \geq 0, \;\; c'(+\infty) = +\infty.$$

In this framework, the welfare function of the economy is defined by $W(q) = \phi(q) - c(q)$ and the efficient allocation ($q^e > 0$) in the market is the solution of $W'(q^e) = 0$ or $\phi'(q^e) = c'(q^e)$. The market demand is given by the maximization of the utility function restricted to the budget constraint. Thus, the market demand is $p(q) = \phi'(q)$.

Now, we will consider two situations. The first one is that of the market being supplied by a private monopoly. In such a case, the firm will maximize $p(q)q - c(q)$ and the monopolist supply ($q^m > 0$) will satisfy $p'(q^m)q^m + p(q^m) - c''(q^m) = 0$, or in terms of the welfare function, $W'(q^m) = -\phi''(q^m)q^m > 0$.

The second possibility is the market being served by a public monopoly and we will suppose that it defines its supply level by maximizing the total welfare, considering its inefficient cost. Therefore, the monopoly managed by the inefficient government will maximize $\phi(q) - (1+\lambda)c(q)$. The first order condition which defines the supply of an inefficient public monopoly ($q^g > 0$) is $\phi'(q^g) = (1+\lambda)c'(q^g)$, or in terms of the welfare function, $W'(q^g) = \lambda c'(q^g) > 0$

Under Hypothesis 1, the welfare function $W(q)$ is twice differentiable and strictly concave (its first derivative is strictly decreasing). Hence both, q^m and q^g are lower than q^e and Figure 1 shows the relative positions of those three possible offer levels.

Intuitively, the greater the inefficiency parameter λ, the lower the amount supplied by the public monopoly. In the following proposition we show that there exists a unique value of that parameter such that, if the inefficiency of the government managing the firm is greater than that value, it is socially better to privatize the firm, namely, the social cost of an inefficient government is greater than the deadweight loss of the monopoly.

Proposition 2.1. *Under Hypothesis 1, there exists a unique $\bar{\lambda} > 0$ such that if $\lambda < \bar{\lambda}$ ($\lambda > \bar{\lambda}$), then $q^g > q^m$ ($q^g < q^m$). When $\lambda = \bar{\lambda}$, it results $q^g = q^m$.*

Proof. Let $F : \mathbb{R}_+ \times \mathbb{R}_{++} \to \mathbb{R}$ be the function $F(\lambda, q) = W'(q) - \lambda c'(q) = \phi'(q) - (1+\lambda)c'(q)$.

Claim 1. *For each $\lambda \geq 0$, there exists a unique $q = q(\lambda)$ such that $F(\lambda, q(\lambda)) = 0$.*

Notice that $q(\lambda) = q^g$, the amount provided by the inefficient monopolistic government.

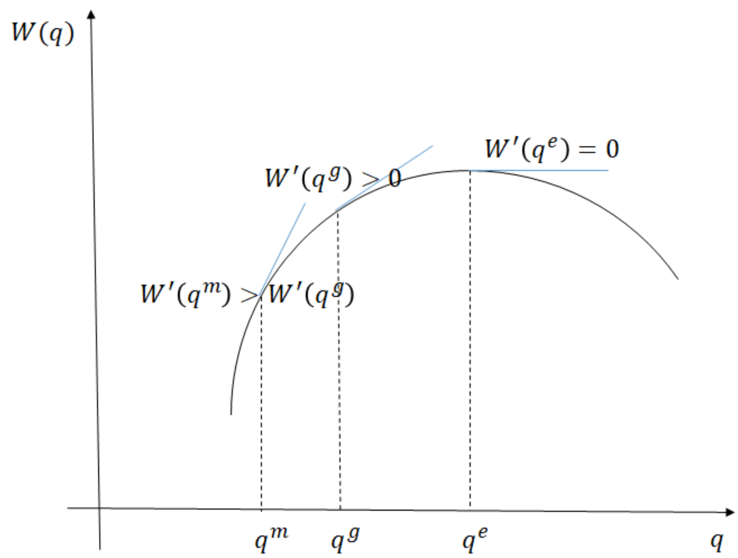

Figure 1: The welfare function and the relative positions of q^e, q^m and q^g.

Proof of claim 1.1. *If $\lambda = 0$, then $F(0, q) = 0$, which amounts to $W'(q) = 0$ and this is true when $q = q^e$, hence $q(0) = q^e$.*

Now, let $\lambda > 0$. Under hypothesis 1 we have that $D_q F(\lambda, q) = \phi''(q) - (1 + \lambda)c''(q) < 0$; $F(\lambda, 0) = +\infty$ and $F(\lambda, +\infty) = -\infty$; therefore, $F(\lambda, \cdot) : \mathbb{R}_{++} \to \mathbb{R}$ is a bijection. Thus, there exists a unique $q = q(\lambda)$ such that $F(\lambda, q(\lambda)) = 0$.

Claim 2. *The function $q(\lambda)$ defined in Claim 1 is strictly decreasing.*

Proof of claim 2.1. *Using the implicit function theorem:*

$$q'(\lambda) = \frac{dq}{d\lambda}(\lambda) = -\frac{D_\lambda F(\lambda, q(\lambda))}{D_q F(\lambda, q(\lambda))} = \frac{c'(q(\lambda))}{\phi''(q(\lambda)) - (1 + \lambda)c''(q(\lambda))};$$

which is strictly negative because of Hypothesis 1. Then Claim 2 is true.

Claim 3. *The function $q(\cdot) : \mathbb{R}_+ \to (0, q^e]$ is a bijection.*

Proof of claim 3.1. *From Claim 2, the function $q(\lambda)$ is an injective map. To prove that it is also a surjective function it is sufficient to verify that its inverse function can be defined in the whole interval $(0, q^e]$. From the equation $F(\lambda, q(\lambda)) = 0$ we can explicitly calculate such inverse function:*

$$\lambda(q) = \frac{\phi'(q)}{c'(q)} - 1,$$

that function satisfies $\lambda(0) = +\infty$ and $\lambda(q^e) = 0$; this proves the Claim 3.

To end up the proof of the proposition, since $q^m \in (0, q^e)$, from Claim 3, there exists a unique $\bar{\lambda} \in (0, +\infty)$ such that $q(\bar{\lambda}) = q^m$ and moreover, if $0 < \lambda < \bar{\lambda}$, then $q^m < q(\lambda) < q^e$, and if $\bar{\lambda} < \lambda$, then $q(\lambda) < q^m$; thus concluding the proof. □

Figure 2 illustrates the shape of the function $q^g = q(\lambda)$, the supply of the monopolistic government, for each level of cost inefficiency that it may have.

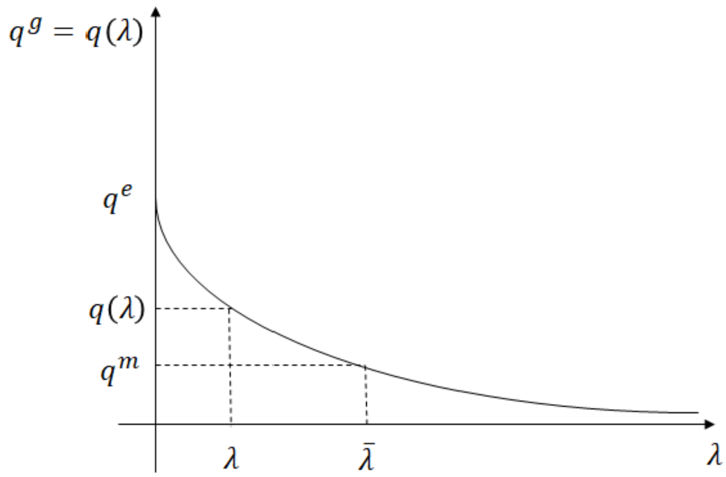

Figure 2: The monopolistic government supply as a function of its cost inefficiency level.

To find the threshold for the government's inefficiency, it is sufficient to solve the equation $q(\bar{\lambda}) = q^m$. It is illustrative to analyze that value in terms of the market structure (demand and cost functions). Table 1 shows the values of $\bar{\lambda}$ for some specific functional forms of the market demand and costs structure.

Table 1: Threshold value of the inefficiency level of the monopolistic government ($\bar{\lambda}$.)

	$c(q) = kq$	$c(q) = (k/2)q^2$
$\phi(x) = Ax - (B/2)x^2$	$(1/2)(Ak^{-1} - 1)$	Bk^{-1}
$\phi(x) = Ax^{1+\epsilon^{-1}}$	$(\lvert\epsilon\rvert - 1)^{-1}$	$(\lvert\epsilon\rvert - 1)^{-1}$

Some interesting features from the illustration in Table 1 is worth noting. When the market demand is isoelastic (the utility function is $\phi(x) = Ax^{1+\epsilon^{-1}}$, where $\epsilon < 0$ is the price-elasticity of demand), the limit value for the cost inefficiency parameter does not depend on the cost function, it only depends on the elasticity of demand ($\bar{\lambda} = (\lvert\epsilon\rvert - 1)^{-1}$). The more elastic the demand, the lower the tolerance to the government's inefficiency. On the other hand, when the demand is a linear function (the utility function is $\phi(x) = Ax - (B/2)x^2$), the marginal cost parameter k affects the parameter $\bar{\lambda}$ negatively. Thus, the greater that parameter, the lower the tolerance to the inefficiency. In this linear demand case, the effect of the demand parameters on the threshold value for the inefficiency depends on the cost function. When the marginal cost is constant, greater market demand (greater value of A) generates greater tolerance to the inefficiency. Whereas in the linear marginal cost case, the greater the market demand (lower values of B), the lower the tolerance to the inefficiency.

Even though the only case in the illustration above that satisfies the Hypothesis 1 is that of the power utility function and quadratic costs, it is not difficult to show that such threshold value $\bar{\lambda}$ exists and is unique indeed.

In the next two sections, we will propose an econometric procedure based on a model of firms regulation to estimate the inefficiency parameter λ in the water supply sector.

3 Detecting the level of cost inefficiency: the Laffont-Tirole Model

Laffont and Tirole (1986, 1993) provides a stylized model of procurement contracts that we can use to address the problem of leading with cost inefficient firms that may inflate their costs in the operation of supplying a good or service to society. We will briefly describe the model (details can be found in the original paper) and the way in which we are going to use it to detect cost inefficiencies in firms operated by the government.

The model is as follows. A firm produces a good with cost function $C = (\beta - e)q + \epsilon$, where $e \geq 0$ is the firm's manager level of effort, $\beta \in [\beta_m, \beta_M] \subset \mathbb{R}_{++}$ is an efficient parameter and ϵ is an ex-post cost disturbance. Providing the good in the amount q reports a consumer surplus $S(q)$ and the planner provides a gross payment of $t + C$ to the firm for production. The utility level of the firm's manager is $U = E[t] - \psi(e)$, where $\psi(e)$ is the disutility of applying the level effort e. Finally, there is social cost of raising monetary resources by the planner of $(1 + \gamma)$.

The planner maximizes the social utility subject to the classical constrains of participation and incentive compatibility on the firm's manager utility, using the principle of revelation on the value of β. Thus, given the value of β, the planner decides the level of effort $e^*(\beta)$ and the supply $q^*(\beta)$. With these, the firm's manager has utility $U^*(\beta) = \int_{\beta}^{\beta_M} \psi'(e^*(\delta))d\delta$, the expected transfer $s^*(\beta) = U^*(\beta) + \psi(e^*(\beta))$ and expected cost $C^*(\beta) = (\beta - e^*(\beta))q^*(\beta)$. In that paper it is proven that the social optimal allocation is implemented by the following incentive scheme that is linear in cost:

$$t(\beta, C) = s^*(\beta) + K^*(\beta)[C^*(\beta) - C], \tag{3.1}$$

where $K^*(\beta) = \frac{\psi'(e^*(\beta))}{q^*(\beta)}$. Notice that the gross payment received by the firm β can be found adding C to both sides of (3.1), resulting in

$$(t(\beta, C) + C) = a_0(\beta) + a_1(\beta)C^*(\beta); \tag{3.2}$$

where $a_0(\beta) = s^*(\beta) + (1 - K^*(\beta))C$ and $a_1(\beta) = K^*(\beta)$. Therefore, we can use the equation (3.2) as a regime-switching linear model (one regime for each value of β) capable of capturing the differences in the cost efficiency of firms with characteristics given by β (given by the parameter $a_1(\beta)$). This will be done in the next section.

4 Empirical application

In this section, we propose an empirical application of the Laffont and Tirole (1986) model described in the former section to estimate the cost inefficiency parameter of monopolistic firms providing water and sanitation services in different regions of the country. It is performed using data from the National Sanitation Information System provided by the National Secretariat of Environmental Sanitation of the Brazilian Ministry of Cities. The sample includes information of the total transfers (revenue) and production costs for 951 water supply companies for the year of 2015, the latest information available. The database includes values only for water supplying services. The companies are classified by the city where they act and by their legal status.

Most of those companies are state-owned, almost 88% of the sample; 9% are private companies; and less than 4% are mixed-capital companies. The latter set includes the largest water supply companies in Brazil. For instance, Sabesp (Basic Sanitation Company of São Paulo State) is the largest country's company. It is responsible for providing water and other sanitation services to 56% of the São Paulo State municipalities.

Those mixed-capital companies are corporations whose stocks are traded at least on the São Paulo Securities, Commodities and Futures Exchange. However, it is worth highlighting that the local government owns more than fifty percent of the shares, which gives him managing control of the company.

Looking closely at the unconditional distribution of the total transfers, it can be seen that 10% of the largest water supply companies hold 90% percent of the total revenue of the sector. Therefore, the data is asymmetric and heavy-tailed.

In order to empirically evaluate the implications of the Laffont-Tirole model described in Section 3, and taking into account the data structure, two econometric methods are used to obtain the estimators for the unobserved efficiency of each firm: a Quantile Regression and a simple Regime-Switching Regression.

The quantile regression estimator is just the solution to a linear programming problem, i.e., if we want to regress $\mathbf{y} = X\beta + \epsilon$, the parameters are estimated by:

$$\hat{\beta}_\tau = \underset{\beta_\tau}{\operatorname{argmin}} \left(\sum_{i:y_i \geq X_i'\beta_\tau} \tau |y_i - X_i'\beta_\tau| + \sum_{i:y_i < X_i'\beta_\tau} (1-\tau)|y_i - X_i'\beta_\tau| \right) \tag{4.1}$$

where the quantile $\tau \in (0, 1)$.

Quantile regressions have some interesting features which make them preferable over Least Squared based estimators: (i) they are more robust to outliers and non-normal errors and (ii) they provide a more complete picture of the data, since it is possible to account for the effect of the variables in X on the entire distribution of y.

Since the objective function in (4.1) is nondifferentiable at the minimum, the solution is obtained by using a simplex algorithm, which is proven to yield a consistent and asymptotically normal distributed estimator. A complete discussion about modeling and inference on quantile regressions can be found in Koenker (2005).

The quantile regression estimator allow us to consider different technological shocks along with the quantiles of the entire distribution of the total transfers y. That is, the technological shocks are conditional on the total transfers amount.

The simple regime-switching regression can be represented by

$$y_i = X_i'\beta_s + \sigma_s \varepsilon_i \tag{4.2}$$

where s is an independent unobserved discrete state (or regime) variable, ε_i is an i.i.d. standard normally distributed error term.

The log-likelihood function associated to (4.2) is

$$\mathcal{L}(\beta, \sigma, \delta) = \sum_i \log \left(\sum_s \frac{1}{\sigma_s} \phi \left(\frac{y_i - X_i'\beta_s}{\sigma_s} \right) \cdot P_s(\delta) \right) \tag{4.3}$$

where $\beta = (\beta_1, \cdots, \beta_s)$, $\sigma = (\sigma_1, \cdots, \sigma_s)$, $\delta = (\delta_1, \cdots, \delta_s)$, $\phi(z) = \exp(-z^2/2)$ and $P_s(\delta) = \frac{\exp(\delta_s)}{\sum_j \exp(\delta_j)}$ is the probability of the state s prevailing.

The function in (4.3) is maximized w.r.t. (β, σ, δ) and the resulting Maximum Likelihood Estimator is consistent, efficient, and asymptotic normal distributed.

By using Bayes' Theorem of conditional probabilities, one can obtain the probability of a firm i being in a regime s conditional on the information available just computing

$$P(C_i \in s|\mathcal{F}) = \frac{\frac{1}{\sigma_s} \phi \left(\frac{y_i - X_i'\beta_s}{\sigma_s} \right) \cdot P_s(\delta)}{\sum_j \frac{1}{\sigma_j} \phi \left(\frac{y_i - X_i'\beta_j}{\sigma_j} \right) \cdot P_j(\delta)}. \tag{4.4}$$

The probabilities in (4.4) will be used to estimate whether a company i belongs to regime s.

In this switching regression model, the technological shocks change randomly across s independent states.

That simple specification for both econometric models is enough for our purpose since the observations for the companies are uncorrelated. Besides, there is only one explanatory variable in the model, the production costs. Additionally, for robustness, some extended specifications including controls for state (Federation Unity where the company is located) and companies' legal personality were estimated. However, the results are not significantly different from the simplest specification. These additional results are not be reported here but they are available upon request.

Therefore, according to the equation (3.2), the basic model to be used in the estimations is

$$transfers = \alpha + \beta \cdot costs + residuals \tag{4.5}$$

where *transfers* are the total transfers (revenue) and *costs* are the production costs, both directly related to water supplying services. The parameter β in (4.5) is the cost inefficiency parameter; namely, it represents the monetary transfer that has to be done to receive the service for each monetary unit of cost involved in the production. The higher the value of β, the more inefficient the corresponding firm is.

Table 2 shows the main results of the two econometric methods estimates for the regression (4.5). At the top of the table we have the quantile regression estimates for $\tau = (0.1, 0.25, 0.5, 0.75, 0.9)$ and at the bottom, the estimates for the switching regression with two regimes.

Table 2: Estimation results

Quantile Regression					
	$\tau = 0.10$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.90$
α_τ	-377166	-263363^{***}	-57668^{***}	41788^{***}	217850^{*}
	(247253)	(32046)	(16335)	(15463)	(128104)
β_τ	0.6387^{***}	0.8132^{***}	0.9352^{***}	1.0307^{***}	1.1851^{***}
	(0.0431)	(0.0014)	(0.0011)	(0.0004)	(0.1052)
Coefficients equality test					
$H_0 : \beta(\tau_h) = \beta(\tau_k)$		$\beta(0.1) = \beta(0.25)$	$\beta(0.25) = \beta(0.5)$	$\beta(0.5) = \beta(0.75)$	$\beta(0.75) = \beta(0.9)$
Restriction Value		-0.1745^{***}	-0.1220^{***}	-0.0955^{***}	-0.1544

Regime-Switching Regression					
	$s = 1$		$s = 2$		$\beta_1 = \beta_2$
α_s	-6671542	(8978312)	66550^{***}	(24509.2)	0.4530
β_s	0.986876^{***}	(0.015768)	0.7927^{***}	(0.00152)	0.0000
$\ln(\sigma)$	18.50803^{***}	(0.058598)	13.353^{***}	(0.05766)	0.0000
Probability	0.173424^{***}	-	0.8265^{***}	-	-

Notes: Robust standard errors between brackets. $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.
H_0 stands for the Null Hypothesis of the Coefficients equality test.

It can be seen that all estimates for the technological shocks (β coefficients) are statistically significant at the 1% level. The quantile regression estimates suggest that the inefficiency parameter β increases along with the quantile τ, i.e., the higher the total transfer, the higher the inefficiency parameter[1]. According to the coefficient equality test, this assessment is true until $\tau = 0.75$. From this quantile on, there is no significant statistical difference among β's.

From the regime-switching regression estimates, the existence of two well-defined regimes (states) is noticeable: on regime $s = 1$, the inefficiency parameter is statistically higher than that

[1] We also estimated quantile regression by percentiles; however the results did not change significantly. For that reason, we choose to report only the results for the specific quantiles shown in the table 2.

of regime $s = 2$, at 1% of significance level[2]. It is also worthy to observe that, broadly speaking, the probability of a firm i belonging to regime $s = 2$ is greater than that of belonging to $s = 1$.

Let's recall that greater values of β correspond to more inefficient firms. The quantile regression approach indicates that the most inefficient companies are those which belong to quantiles from $\tau = 0.75$ on, i.e., the 25% biggest companies in the sample. The regime-switching regression suggests that those companies belonging to the state $s = 1$ are the most inefficient ones. Once the likelihood function (4.3) is evaluated, one has the estimated probabilities vector for (4.4), $\hat{P}(C_i \in s|\mathcal{F})$. Thus, the company i is on the regime $s = 1$ if $\hat{P}(C_i \in s|\mathcal{F}) > 0.5$.

An interesting exercise can be executed with these results in connection with the model in Section 2. In that section, we have that the cost of a monopoly operated by the government is inflated in a factor $(1 + \lambda)$. With the parameter β estimated in each procedure above (quantile regression and regime switching regression) we can infer a value for the parameter λ. For example, in the regime switching regression, the ratio β_1/β_2 can give us an estimate of $(1 + \lambda)$, namely $\beta_1/\beta_2 = 0.986876/0.7927 = 1.245$; thus, $\lambda = 0.245$ for this regression method. On the other hand, since the quantile regressions allow us to identify four levels of efficiency, three different λ's can be obtained. Considering that the most efficient companies have $\beta_{0.1} = 0.6387$, we have $\lambda_1 = \beta_{0.25}/\beta_{0.1} - 1 = 0.273, \lambda_2 = \beta_{0.5}/\beta_{0.1} - 1 = 0.464$ and $\lambda_3 = \beta_{0.75}/\beta_{0.1} - 1 = 0.734$. Thus, one can infer that the inflation of the levels of cost inefficiency is increasing with the size of the company.

We can ask if those values are acceptable as parameter values for the cost inefficiency. Recall that, as listed in Table 1, if the price-elasticity of the demand is $\epsilon < -1$, then the maximum tolerance to cost inefficiency of the government operating the firms in the sector is $\bar{\lambda} = (|\epsilon| - 1)^{-1}$. We have in the literature several studies regarding the value of the price-elasticity of water demand. Hewitt and Hanemann (1995), used a discrete/continuous choice model of the residential demand for water under block rate pricing to estimate a price elasticity near -1.6. Espey et al. (1997) performed a meta-analysis of that value using 24 journal articles published between 1967 and 1993 studying the residential demand for water. In those articles the price elasticity estimates range from -0.02 to -3.33. More recently, Klaiber et al. (2012) found for the same type of demand an elasticity varying from -1.93 in winter to -0.45 in summer in normal years.

Regarding the demand for agricultural water, Schoengold et al. (2006) found an inelastic demand function with elasticity parameter -0.79 for India while Davidson and Hellegers (2011) found that it varies from -2.12 to -0.44. For Brazil, de Melo and Neto (2007) reported, as a result of their model I, a price-elasticity for residential water of -1.008. Using the maximum values of $|\epsilon|$ of the studies above, Table 3 reports the maximum tolerance to cost inefficiency in each corresponding markets.

Table 3: Maximum cost inefficiency values in the corresponding studies

Study	$\bar{\lambda}$
Hewitt and Hanemann (1995)	$(1.6 - 1)^{-1} = 1.66$
Espey et al. (1997)	$(3.33 - 1)^{-1} = 0.43$
Klaiber et al. (2012)	$(1.93 - 1)^{-1} = 1.07$
Schoengold et al. (2006)	$+\infty$
Davidson and Hellegers (2011)	$(2.12 - 1)^{-1} = 0.89$
de Melo and Neto (2007)	$(1.008 - 1)^{-1} = 125$

[2]It was also estimated switching regressions with more than two states; however, the regime parameters were not significantly different among them.

Of course, if the elasticity is in $[0, 1]$ there is no possibility of exploration of the sector by a private initiative (not without regulation). That is the case for the study by Schoengold et al. (2006), thus we set $+\infty$ as the tolerance. In the other cases we can verify that the more elastic is the water demand, the lower is the tolerance for inefficiency. In Brazil, the tolerance is enormous due to the very low price-elasticity of water demand reported in de Melo and Neto (2007).

Now, let us go back to our results and see the distribution of companies according to their legal status and inefficiency. Table 4 shows the distribution of the inefficient companies pointed out by each econometric method according to their legal status. 236 companies are considered the most inefficient ones by the quantile regression and 165 companies by the regime-switching regression. Considering proportions, the results for both models are quite similar: most of the inefficiency is found in public companies (70% and 63%, respectively), private companies are 17% and 20%, and mixed-capital companies are 13% and 17%, respectively. The quantile regression estimates indicate more companies than the regime-switching regression. Most of this difference is concentrated in public companies.

Table 4: Inefficient companies distribution

Method	Companies' legal personality			Total
	Mixed-capital	Public	Private	
Quantile Regression	30 (13%)	165 (70%)	41 (17%)	236 (100%)
Switching Regression	28 (17%)	104 (63%)	33 (20%)	165 (100%)
Difference	2 (3%)	61 (86%)	8 (11%)	71 (100%)

When we identify the firms classified as inefficient by both methods, 147 companies are found. This represents around 62% of quantile regressions indications and 89% of the regime-switching regression indications. This finding implies that only 11% (18 companies) of those indicated by the regime-switching regression are among the 25% largest companies in the sample. It is also worth recalling that all these companies are responsible for water supply services to more than half of Brazilian population.

As mentioned in the beginning of this section, the mixed-capital companies, in spite of their low participation in our sample (4%), figure among the largest water supply companies in Brazil. There are 31 mixed-capital companies in the sample, and 30 of them are in the set of the 25% largest companies. Thus, inefficient according to quantile regressions estimates, and 28 of them are inefficient according to the regime-switching regression estimates.

At first glance, this result may sound surprising, since the argument for these companies becoming mixed-capital is the achievement of higher efficiency levels. Recall that when companies are listed in a stock exchange market, it is required that they have a well-defined corporate governance system.

For that reason, our findings point out in another way. Despite these companies being open to the stock market, they are government-controlled. The federation state where the company is headquartered owns more than 50% of the total capital or the golden-share. Thus, the local government can directly choose the board of directors and the CEOs of the company. Since these nominations have a strong political-party interference, the inefficiency captured by our empirical analysis makes sense.

5 Final remarks

In this work, we analyze the optimal social decision between the use of a public monopoly to provide a good/service or the use of a private monopoly for this end. When the government is entitled to explore the sector, it is engaged in cost inefficiencies arising from problems of asymmetric information (moral hazard of the managers or loss of incentives), lack of monitoring schemes, discontinuity of the party in charge of the government, or even corruption. All those defects may increase the real cost of production and most of them are not present in the private initiative. Such dichotomy must be taken into account when deciding the privatization or not of a firm.

We provided a simple theoretical framework to analyze that problem and an empirical procedure to measure the size of the cost inefficiency that a firm may have. From the theoretical analysis we show under classical hypotheses on the market demand and cost function, that there exists a threshold for that inefficiency level above which it is preferable to let the private sector explore the monopoly. That threshold depends on structural parameters, and in general, increases as the market demand is greater, showing that inefficiency of the government is more tolerable in sectors with high demand.

For the empirical analysis, we based our econometric model on the firm regulation model proposed by Laffont and Tirole (1986), where the optimal scheme of incentives is a linear relationship between the total revenue received by the firm and the cost incurred in production. Using data from the National Sanitation Information System of Brazil regarding the revenues and costs of local providers of water and sanitation services (which are local monopolies indeed), we estimated that equation. Due to the large spectrum of sizes of the companies, we perform two estimations: the first using a quantile regression method, and the second, a regime-switching regression with unobservable state. The surprising (or not) result was that both methodologies pointed out that the most cost inefficient firms were the government-controlled companies offering the good/service. Specifically, each monetary unit of production cost is inflated at least by 25 cents and may reach about 73 cents when the sector is attended by an inefficient firm. Despite those values may seem large, we presented a table with several studies on the price-elasticity of water demand revealing that, due to the low elasticity in that sector, it may be tolerable to let the inefficient government managing the supply of water and sanitation services.

Our findings contribute to the discussion of public policies on privatization decisions, giving a technical criterion based on the market demand and technological structures to chose the best form of exploring an economic sector. At the same time, they propose a technique to measure the size and localization of firms with inefficient costs serving the economy.

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