

Impact of Private Sector Participation in the Provision of Water Services in Brazil: Empirical Analysis and Policy Recommendations

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Brazil has been experimenting with Private Sector Participation (PSP) in the water and sewage sector since the mid-nineties. In this paper we study past and ongoing experiences of private supply of water in Brazil and assess their impact on access (coverage). We use different estimation methods and datasets to investigate the existence of differences between municipalities where there is private participation in water supply and those where there is not. Our results suggest that PSP in Brazil has delivered higher access to water services and provide evidence that it has benefited poor households. The policy-making impact of our findings is significant, so we also offer some policy recommendations.

Keywords: Water Services, Access, Panel Data, Private Sector Participation

JEL Classification: L33, L51, L95

I. Introduction

According to the World Health Organization, unsafe water, inadequate sanitation and insufficient hygiene are ranked fourth in the list of leading health risk factors in the world (WHO, 2009). While some countries are making steady progress in providing access to sanitation and drinking water services, many others are still struggling to increase coverage significantly and have failed to reduce the associated disease burden on their populations (WHO, 2010). There is no question that to increase access to safe drinking water and improved sanitation should be a priority for countries where coverage rates have not yet met acceptable standards, but it is not so clear how that is to be achieved.

In many developing countries, state-owned enterprises provide most of the water and sanitation services, but Private Sector Participation (PSP) has become a viable option in the last couple of decades. A recent study published by the World Bank (Gassner, et al., 2009) finds that PSP has a strong positive effect on several measures of performance in the water and sanitation sector, including coverage and quality of service, corroborating other results in the literature. On the other hand, it finds no robust evidence that private management of water supply companies changes either investment or the average residential tariff.

The majority of studies on PSP in the water and sewage sectors address the relative efficiency of private and public companies. Most of them are single-country studies that either use frontier techniques (like Data Envelopment Analysis and Stochastic Frontier) or estimate production and cost functions to evaluate efficiency differences (see e.g. Walter, et al., 2009, and the references therein). The results are mixed, in the sense that some of them show a positive impact of private ownership on company efficiency, whereas others find no discernible difference or

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even posit that publicly owned utilities are more efficient. Papers that study the Brazilian case are Sabbioni (2008) and Seroa da Motta and Moreira (2004).

In this paper we strive to make a contribution to the literature by departing from the focus on efficiency issues and investigating instead the impact of PSP on the welfare of users, as measured by the access (also called coverage) rates. We use data stemming from the Brazilian experience with PSP in the water sector not only to compare average access rates, but also to examine the impact of private participation on the supply of water to lower income municipalities. We do not investigate the sewage segment of the sanitation sector, however, because the data we had access to was skimpy.

We are aware of only a few studies similar to ours in scope. Wang et al. (2011) work with a panel dataset of thirty-five major cities to examine the effects of private sector participation on the performance of the water supply sector in China. Their main conclusion is that PSP improves production capacity and coverage rates of urban water supply. Lee (2011) uses household data to study the impact of privatization on access and affordability in the Malaysian water supply sector, but his results are unclear. He concludes that privatization does not seem to have improved access to treated water in Malaysia. And Clarke et al. (2009) explore the effects of private sector participation on coverage in a cross-section study of Argentina, Bolivia and Brazil. They identify an increase in the share of households connected to piped water and sewerage following privatization, but suggest that private sector participation, per se, may not have been responsible for that improvement. The reason they carried out a cross-section study was that their dataset, based on household surveys, had a limited number of observations for each country. Even after bundling all the data together, their sample had data on fewer than fifty cities in the three countries. That is a major distinction between their work and ours: Whereas we have data on thousands of Brazilian municipalities, they are restricted to two Brazilian locations where PSP took place. Our superior dataset allows us to obtain more robust results and carry out more sophisticated analysis.

Private sector participation in the water and sewage sector in Brazil has been tried in many parts of the country since the mid-nineties, but not without considerable opposition. It has been argued, for instance, that profit-maximizing private companies will charge prices that low income families cannot afford. Given their relatively low income-elasticity of demand for water¹, low income families would spend a disproportionately high share of their budget on water bills or simply not pay them at all, eventually being disconnected from the system. Another objection is related to the externalities generated by the consumption of water. The supply of clean water helps prevent some of the most common, usually contagious, diseases. Improved health leads to higher productivity and faster economic and social development. Private companies, however, only respond to market signals, and thus would tend to supply a suboptimal amount of water (undersupply). Finally, there is the natural monopoly argument. The existence of substantial economies of scale together with the long life of assets would constitute insurmountable barriers to entry (Noll, et al., 2000), leading to very little competition in the market, if any at all². Given their monopoly position, private companies would raise tariffs above cost, generating social losses. Although there is evidence contradicting that view (see e.g. Estache, et al., 2001), it is

¹ This happens because low income families usually consume at survival rates (50 l/d according to the World Health Organization), whereas high income families have other, more superfluous, uses for water, such as swimming pools, lawn irrigation etc.

² There are some (not very close) substitutes for piped water supply, like pumped wells, rainwater catchments and private vendors, but they do not represent significant competition to regular water provision.

still widely used as an argument against privatization. It is evident that these objections can be addressed through proper regulation and social policy instruments (Shleifer, 1998), but it is not our purpose to elaborate on that in this paper.

We apply several estimation methods and use two datasets to evaluate the effects of private participation on access to water services in Brazil. First we use a panel containing mostly financial and operational indicators, at the municipality level, to estimate panel data models where access rates are explained by a dummy for private provision of water service and other variables. Ideally, we would like to include household characteristics in the model, but the household surveys published by IBGE, the Brazilian Institute of Geography and Statistics, do not allow the identification of the municipality where the household is located. Our second approach is to carry out an analysis of the type "control and treatment" using a difference-in-differences estimator. The control group is composed of the municipalities that did not privatize their water service, and the treatment group, of those that did. The dataset is a panel of two years, 1991 and 2000, and the source of the data is the Brazilian census.

The paper is divided into six sections, including this Introduction. In section 2 we provide, as background, a brief historical account of the water and sewage sector in Brazil and spend some time describing the participation of private capital. In Section 3 we present some indicators on access to water supply in Brazil that bear out the main issues in the sector. In section 4 we lay out the results from a plethora of estimations that measure the effects of private provision on access to water services, and discuss these results in section 5. Section 6 concludes.

II. The Water and Sewage Sector in Brazil

A. Brief Historical Account

Up until the 1960's, the provision of water and sewage services in Brazil was very deficient, lack of appropriate water and sewage treatment, inefficient operation and faulty regulation being the norm. Moreover, there were different management models in place. Some municipalities provided water and sewage services independently, while others formed consortia with neighboring municipalities. The most successful model was arguably one where state administrations were in charge of the entire production process, including planning, construction and operation (Turolla, 2002).

Under the military rule that started in 1964, most water and sewage projects were financed by the National Housing Bank (BNH). In order to have access to the financial resources made available by BNH, municipalities were required to supply water and sewage services through autonomous departments or mixed ownership companies (Turolla, 2002). This resulted in a model where municipalities played a predominant role.

The introduction of the National Sanitation Plan (Planasa) in 1971, however, changed that picture. The plan laid out investment schedules for the sector, as well as tariff, credit and other sector policies. It also promoted the creation of regional water and sewage companies owned by state governments and encouraged municipalities to grant them long term concessions in exchange for financial resources (coming mostly from BNH). This centralization was justified at the time based on the alleged existence of economies of scale in supplying services to large metropolitan areas, the possibility of reducing planning costs, and the need to introduce cross subsidies (more profitable regions subsidizing less profitable ones).

The incentives faced by the regional (state) companies under Planasa were such that construction and expansion plans were favored at the expense of operations (Rezende, 1996). Loans from BNH, for instance, were not available to finance companies' operations, a consequence of the government's drive to expand infrastructure. This eventually resulted in the deterioration of water and sewerage systems, leading to high system losses. At any rate, coverage of water provision in urban areas in Brazil increased from 60 percent in 1970 to 86 percent in 1990 under Planasa, while coverage of sewage collection increased from 22 percent to 48 percent in the same period of time (Seroa da Motta, 2004).

By the end of the 1980's, however, the performance of the highly centralized Planasa system had worsened significantly. The Brazilian economy was facing a hyperinflationary process that led the government to keep companies' tariffs under tight control to tame inflation. Dwindling investments due to lack of appropriate financing (BNH ceased to exist in 1996 and there was a sharp decrease in foreign capital inflows), political meddling and mounting debt anticipated a gloomy future for the water and sewage sector. Not even the economic stability achieved after the 1994 "Real Plan" was enough to restore the sector's financial health and ability to meet increasing investment needs.

In 2001, in an attempt to restructure the water and sewage sector, the Brazilian government drafted a bill, known as PL 4.147, and sent it to Congress. It gave water and sewage companies administrative and financial autonomy, and established price-setting principles and concession criteria. Moreover, it gave states (instead of municipalities) the power to grant concessions in metropolitan areas. The bill ran into the opposition of many stakeholders and stalled. Municipalities were against the provision that gave states the power to grant concessions in metropolitan areas, for obvious reasons. There was also resistance to its directives regarding privatization, universal service and regulation.

A second shot at reform was taken by the administration of President Lula da Silva, who came to power in January of 2003. After a long period of discussions and modifications to earlier drafts, the bill was approved by Congress and sanctioned by President Lula da Silva on January 5, 2007. It does not clearly define concession rights, a matter that apparently will have to be decided by the country's highest courts, but it does require concessionaires (regional water and sewage companies) to be reimbursed for past investments in case their contracts are unilaterally terminated by municipalities. It also establishes criteria for municipalities and states to access federal money and sets up civil councils that have a say in regulatory matters such as price-setting and termination of service. Unfortunately, performance indicators have not improved much since the law went into effect, and the need for investments in water and sewage today is as high as it was a decade ago (IBGE, 2011).

B. Private Sector Participation

The water supply and sewage sector in Brazil today is still a reflection of the main guidelines established by Planasa. In particular, regional companies holding concessions from municipalities are still the dominant force. Municipal provision of water and sewage services is found mainly in larger southern and southeastern states, either through agencies under direct municipal control, autonomous agencies or municipal companies. There are also a small but significant number of cases of private companies holding partial (either water or sewage) or full (both water and sewage) municipal concessions.

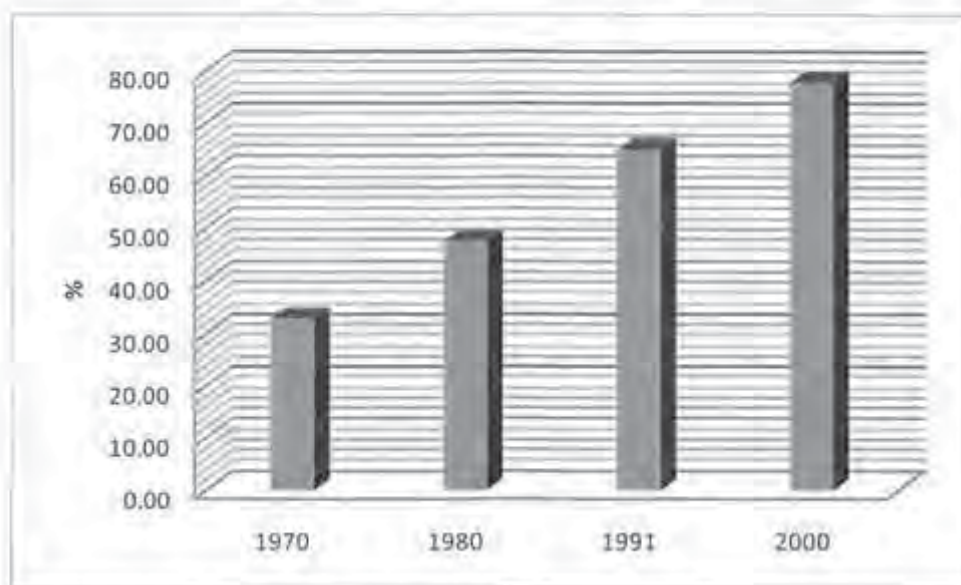
Brazil has been experimenting with Private Sector Participation in the water and sewage sector since the mid-nineties. In the North region of Brazil, only a handful of municipalities in the states of Amazonas and Pará are served by private operators, but in Tocantins, over a hundred municipalities have opted for private supply. In the Midwest, private water supply can be found in the states of Mato Grosso and Mato Grosso do Sul, whereas in the South the states of Paraná and Santa Catarina lead the way. It is in the Southeast region, however, that private participation is more significant, with over 8 million people served by private companies in the states of São Paulo, Rio de Janeiro, Espírito Santo and Minas Gerais (ABCON, 2011).

Capital structure choices and price-setting behavior are variable. In some cases, companies are fully equity-financed, while in others relatively sophisticated financing schemes mixing equity and debt were set up³. Tariff structures are in line with those adopted by the sector in the past, mainly based on minimum consumption rates, increasing block-rate tariffs, and price differentiation (by user groups). In some cases, price cap regulation was implemented. Concessions are the contractual instrument of choice between companies and local governments in most cases.

III. Indicators of Access to Water Services in Brazil

In this section, we describe the evolution of the water sector in Brazil. Access to water services increased significantly in Brazil from 1970 to 2000, as can be seen in Figure 1, as a result of the heavy investment made during the Planasa era. The percentage of households with access to piped water supply (through house connections) increased from 32.81 percent in 1970 to 77.82 percent in 2000.

Figure 1: Households with Access to Piped Water Supply through House Connections (%) – 1970, 1980, 1991, 2000

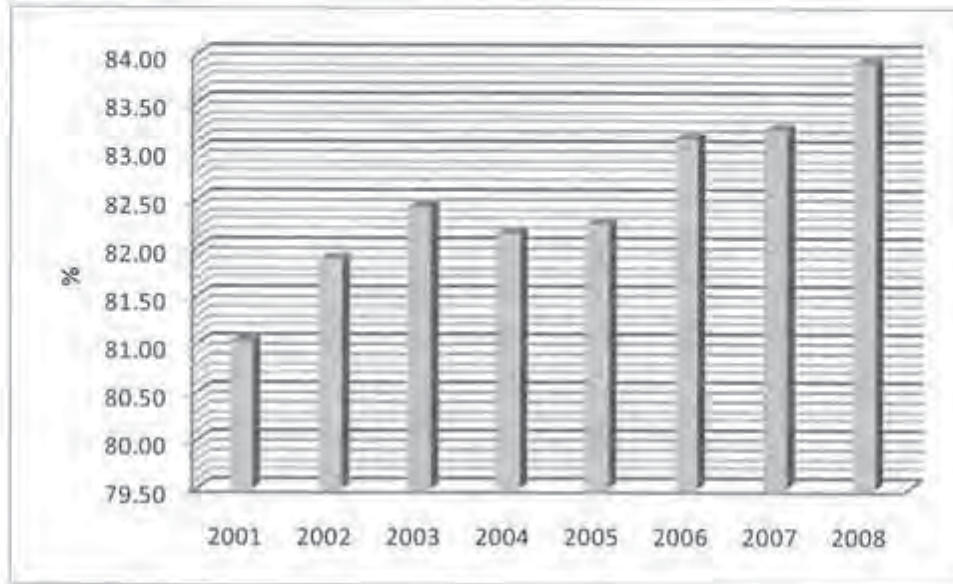


Source: IBGE – 1970, 1980, 1991 and 2000 demographic censuses.

³ Many loans pledged to new private concessionaires by private and public institutions ended up not materializing (Parlatore, 2000).

Figure 2 presents more recent annual data on access to water services⁴. We notice a steady increase in access rates from 2001 to 2008, but falling short of the 85 percent mark.

Figure 2: Households with access to piped water supply (%) – 2001-2008



Source: IBGE – PNADs

Access to public services in Brazil is very unevenly distributed. Water supply is no exception. The following table shows the evolution of access to water services by income bracket (in multiples of the minimum salary⁵) for the period 2001-2008.

⁴ The source of this data is the National Household Sample Survey (PNAD). The definition of access to water supply used in this survey is a little different than that used in Figure 1. It includes households with any type of access to piped water supply, not only through house connections. Both the PNADs and the censuses can be found at www.ibge.gov.br.

⁵ The minimum salary was R\$380 (three hundred and eighty Reais) in January of 2008, approximately US\$214 at the average exchange rate at the time.

Table 1: Households with Access to Piped Water Supply (%) by Income Group – 2001-2008

Income class	2001	2002	2003	2004	2005	2006	2007	2008
Up to 1 MS	61.14%	64.13%	66.92%	66.72%	68.07%	68.46%	68.86%	71.01%
From 1 to 2 MS	71.17%	73.19%	75.28%	74.83%	75.14%	77.11%	77.16%	78.03%
From 2 to 3 MS	78.34%	79.76%	81.14%	79.68%	80.88%	82.73%	82.97%	82.98%
From 3 to 5 MS	85.75%	85.58%	86.46%	86.26%	86.52%	86.86%	87.54%	87.62%
From 5 to 10 MS	90.85%	91.63%	91.24%	91.10%	91.39%	91.99%	91.68%	91.56%
From 10 to 20 MS	94.06%	94.17%	93.77%	93.11%	94.14%	94.12%	94.24%	93.56%
More than 20 MS	94.69%	95.60%	94.76%	94.70%	94.25%	94.87%	93.94%	95.05%
No labor income	78.97%	79.08%	82.83%	80.10%	82.04%	82.17%	78.82%	82.70%

Source: IBGE – PNADs

Notes: MS = minimum salary; No labor income refers to households whose only source of income is cash aid received from the government.

Despite the significant increase in coverage for families in the lowest income brackets, the gap between them and those in the highest brackets is still very large. In 2008, for instance, the access rate for households in the top income bracket (more than 20 MS) was 24.04 percentage points above that for households in the bottom bracket (up to 1 MS). The distribution of access to piped water by region and location (urban or rural) is also very uneven, as can be seen in the table below.

Table 2: Households with Access to Piped Water Supply (%) by Region and Location – 2001-2008

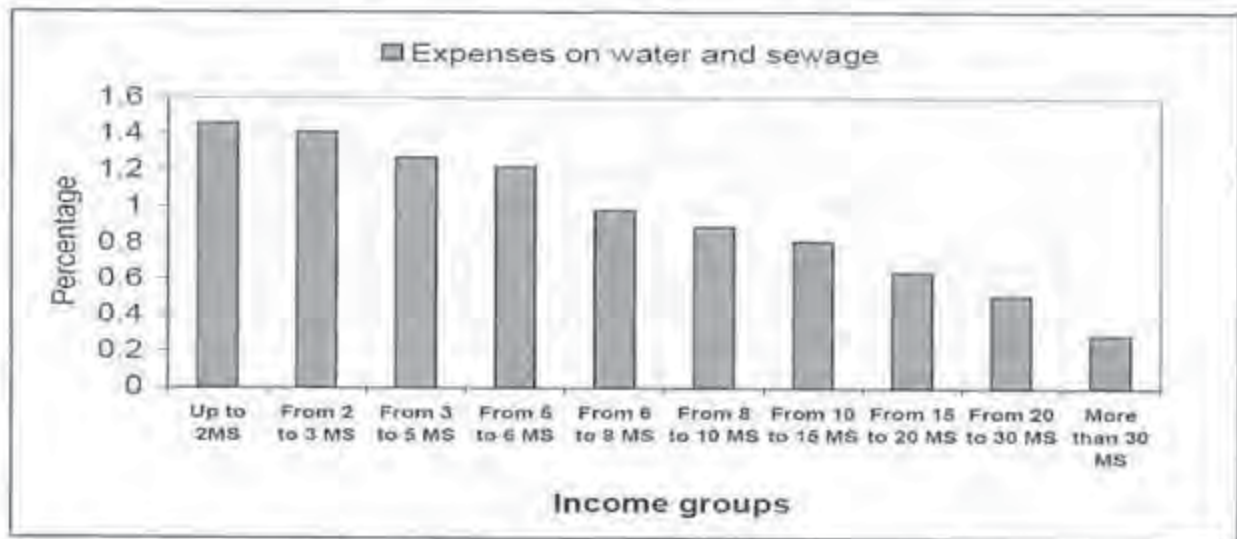
Region		2001	2002	2003	2004	2005	2006	2007	2008
North	Total	62.23%	62.26%	64.78%	55.44%	54.92%	56.56%	56.29%	58.30%
	Urban	63.50%	63.63%	65.96%	67.27%	66.64%	68.70%	67.21%	68.67%
	Rural	29.07%	21.95%	32.18%	19.20%	17.99%	16.57%	18.72%	21.81%
Northeast	Total	69.26%	70.66%	72.10%	73.16%	73.89%	75.10%	75.75%	78.02%
	Urban	87.78%	88.89%	88.92%	89.97%	90.35%	91.22%	91.67%	92.55%
	Rural	21.02%	21.96%	26.76%	26.51%	29.01%	30.03%	31.16%	36.54%
Southeast	Total	90.45%	90.91%	90.96%	91.38%	91.38%	91.90%	91.64%	91.84%
	Urban	96.36%	96.31%	96.32%	96.54%	96.54%	96.99%	96.69%	96.73%
	Rural	22.14%	25.05%	25.13%	27.27%	28.11%	28.67%	28.52%	30.46%
South	Total	81.70%	82.93%	83.16%	83.83%	83.94%	84.72%	84.80%	84.05%
	Urban	94.20%	94.93%	94.60%	94.83%	94.66%	95.17%	95.30%	94.63%
	Rural	23.38%	25.81%	27.27%	29.34%	29.93%	31.58%	30.52%	30.00%
Midwest	Total	75.51%	76.82%	77.15%	78.92%	78.22%	79.53%	80.76%	81.34%
	Urban	85.20%	86.29%	87.35%	89.02%	88.42%	89.84%	90.86%	90.52%
	Rural	13.13%	13.91%	13.44%	15.96%	15.50%	14.71%	16.01%	18.06%

Source: IBGE – PNADs

Despite their relatively high growth rates in the period 2001-2008 (for the country as a whole, it was almost 50 percent), coverage rates in rural areas are still significantly lower than those in urban areas in all geographic regions, especially in the North and Midwest regions. In addition, overall coverage rates in the least developed regions of Brazil, the North and the Northeast, are lower than those in the more developed regions. The 2008 coverage rate of only 58.30 percent in the North of Brazil is particularly worrisome.

Affordability of water services in Brazil is also a critical issue (but we don't address it in our econometric analysis). We call attention to the percentage of household income spent on water and sewage payments. The figure below shows the average percentage of household income spent on water and sewage bills by income groups, where these groups are defined in terms of multiples of the minimum salary on January 15, 2003.⁶

Figure 3: Affordability by Income Groups



Source: IBGE – 2002-2003 Survey of Household Budgets (POF)⁷

The graph above is striking evidence of how water and sewage bills are much more burdensome for low-income families than high-income families. For instance, while families with incomes no greater than two minimum salaries (MS) spend 1.46 percent of their monthly budget on water and sewage payments, families in the top tier, those who earn more than 30 MS, only spend 0.29 percent of their monthly budget on those services.

IV. Impact of Private Provision on Access to Water Service

The depiction in the previous section of access to water supply in Brazil calls for an investigation of whether or not private provision of water services has had any impact on access rates in Brazil. We use two separate datasets to try and estimate the effect of private provision on access to water supply. The first is the National Sanitation Information System (SNIS), published

⁶ The minimum salary was R\$200 (two hundred Reais) then, approximately US\$58 at the average exchange rate at the time.

⁷ This is the latest survey available.

by the Program for the Modernization of the Sanitation Sector (PMSS) of the Brazilian Ministry of Cities. The second is the Brazil Human Development Atlas (HAD), a publication of the United Nations Development Programme in Brazil. The two sets of regressions will be presented separately.

A. Estimations Using the SNIS Dataset

The SNIS database includes information on around 170 indicators related to economic, operational and quality indicators for water and sewage services over the period 1995-2008 for a large number of municipalities. The municipalities in the sample may vary from year to year, due mainly to changes in the set of service providers at the local level and to the fact that participation in the survey is not mandatory. In addition, data from 1995 to 2000 is sparse and not very reliable. In order to minimize those problems, we reduced the size of our (unbalanced) panel to 1554 municipalities and worked with data from 2001 to 2008, totalling 11,964 observations.

We are interested in estimating the relationship between access to water services and the type of company that provides such services, whether private or public. Our model is of the form

$$ACCESS_{it} = \alpha_0 + \alpha_1 DPRIV_{it} + \sum_{k=1}^K \alpha_{k+1} x_{ikt} + a_i + u_{it}, \quad i = 1, K, N, t = 1, K, T$$

where the x_{ikt} 's are the observations of the K other explanatory variables besides $DPRIV$, a_i is the unobserved effect and u_{it} is the idiosyncratic error. The dependent variable is a measure of service coverage that we call $ACCESS$, defined as population with access to water service over population of the municipality. $DPRIV$ is a dummy variable that takes value one if water service is provided by a company under private management and zero otherwise. We postulate that the company's decision regarding how much service coverage to provide depends on whether it is privately or publicly managed. A private company seeks maximum profits whereas a public company might be pursuing social goals, and that might result in different decisions.

The unobserved effect a_i does not vary with time but varies with municipality (our cross-section unit), and as such captures all time-invariant (at least during the time span of the sample) unobserved factors that affect the dependent variable. For instance, factors such as the political party in power and geographical characteristics are included in a_i . It can also be thought of as capturing historical aspects particular to each municipality, like the pre-sample average access rate, the preferences of the population regarding public versus private provision of public services etc.

When this model (the other explanatory variables will be made explicit below) is estimated by first-differences, fixed effects and random effects, the results vary substantially with the estimation method. The fact that the two first methods produce very different results is surprising. The main reason for this is that the explanatory variable $DPRIV$ is binary and doesn't change much over time. More precisely, there are not many instances when municipalities switch from private to public provision or vice-versa. The first-difference estimator is the result of a pooled regression of the variables in (time) difference, and there are few observations where the differenced $DPRIV$ is not equal to 0 (it can take only three possible values, 0, 1 and -1). This lack of variation is responsible for the non-significance of the variable $DPRIV$ obtained with first-

difference estimation. When the fixed effect estimator is used *DPRIV* becomes significant. That can be attributed to the fact that there is more variation in the explanatory variable.⁸

When the random effects estimator is used, the results differ considerably from those obtained with the other two methods. That can also be explained by the presence of the binary explanatory variable *DPRIV*, better handled by the random effects method.⁹

Let's now specify the other explanatory variables in the model. Since *T* is small compared to *N* in our sample, it is a good idea to add time dummies to take into account secular changes that have not been modelled. We use time dummies for the years 2002 and 2008, named *D2002* to *D2008*, respectively.

The cost of providing water services is certainly an important factor to be included in the model. We use as proxy to cost variables the variables *DENSITY*, *EXCONNECT*, *NUMCONNECT*, *PRODUCTIVITY* and *INVEST*. *DENSITY* is defined as number of water economies¹⁰ by connection, and tries to measure possible economies of density. *EXCONNECT* is the extension of the water system divided by the number of water connections. It tries to capture geographic effects, for its value depends on the topography of the terrain where the municipality is located. *NUMCONNECT* is the number of water connections and accounts for possible (economies of) scale effects. A large number of water connections is allegedly associated with significant economies of scale, and that, in turn, should produce higher access rates.

The variable *PRODUCTIVITY* is defined as the number of employees over thousand water connections and therefore is something under management control. *INVEST* is the company's investment in the water supply system, measured in Reais (the Brazilian currency). The last explanatory variable is *GDPPERCAP*, the municipality's per capita GDP. It is a proxy for the average income of the municipality's population.

The equation to be estimated is thus:

$$\begin{aligned} ACCESS_{it} = & \alpha_0 + \alpha_1 DPRIV_{it} + \alpha_2 D2002_t + \alpha_3 D2003_t + \alpha_4 D2004_t + \alpha_5 D2005_t \\ & + \alpha_6 D2006_t + \alpha_7 D2007_t + \alpha_8 D2008_t + \alpha_9 DENSITY_{it} \\ & + \alpha_{10} EXCONNECT_{it} + \alpha_{11} NUMCONNECT_{it} + \alpha_{12} INVEST_{it} \\ & + \alpha_{13} PRODUCTIVITY_{it} + \alpha_{14} GDPPERCAP_{it} + a_i + u_{it} \end{aligned} \quad (1)$$

$$i = 1, \dots, N, t = 1, \dots, T$$

This equation can be looked at as one describing the factors that affect the water company's decision regarding how much access to provide. It is possible, however, that *ACCESS* and *DPRIV* are simultaneously determined, which would render *DPRIV* endogenous. We will come back to this issue later.

⁸ Recall that the fixed effects estimator is the result of a pooled regression of the (time) reduced model, where the levels of the variables are replaced by their differences to the time average, i.e., x_{it} is replaced by $x_{it} - \bar{x}_i$. The time averages depend on the sequence of ones and zeros assumed by the variable *DPRIV* for each unit (municipality), which means that there is more variation in $DPRIV_{it} - \overline{DPRIV}_i$ than in $\Delta DPRIV_i$.

⁹ In fact, since the random effects estimator is the pooled OLS estimator of an equation of type $y_{it} - \lambda \bar{y}_i = \beta_0 (1 - \lambda) + \sum_{j=1}^k \beta_j (x_{ijt} - \lambda \bar{x}_{ij}) + (v_{it} - \lambda \bar{v}_i)$, where $\lambda = 1 - [\sigma_v^2 / (\sigma_v^2 + T\sigma_u^2)]^{1/2}$, it can handle explanatory variables with limited variation (and no variation at all) much better than the other two methods.

¹⁰ An economy is defined as a dwelling, apartment, office, shop, industry or similar unit within a building with access to water supply.

When fixed effects or first difference methods are used, time-constant explanatory variables are not identified, as mentioned before. Also, in cases where the key explanatory variables do not vary much over time, FE and FD methods can lead to imprecise estimates, and that seems to be the case with our estimations. Thus, when we are primarily interested in the effect of a time-constant or almost time-constant variable in a panel data study, the robustness of the FE estimator to correlation between the unobserved effect and the explanatory variables is practically useless. The alternative then is to use a random effects model, which is valid only under the assumption that the unobserved effects are not correlated with the explanatory variables. We performed a Hausman test to select between the fixed and random effects models, and it detected the existence of such correlation¹¹. This implies random effects will produce inconsistent estimators of the parameters.

The solution to this dilemma is to use some sort of instrumental variables approach together with a random effects model. We apply two of them to our data. The first IV approach requires the existence of instrumental variables that are not correlated with $\alpha_i + u_{it}$. In this case, a GMM estimator called the error components 2SLS – EC2SLS (Baltagi 1981), can be used. The second approach is known as the Hausman-Taylor method (Hausman and Taylor 1981)¹², which allows some but not all of the regressors to be correlated with α_i .

In order to apply the EC2SLS method, we need to find appropriate instrumental variables for the endogenous variables. We identified two endogenous variables in the original model, namely *DPRIV* and *NUMCONNECT*. *DPRIV* is endogenous because it is correlated with features of the municipal administrations that are not included in the model as explanatory variables and are thus part of the error. Examples are competence, corruption level, and regulatory experience. In addition, it is likely that *ACCESS* and *DPRIV* are simultaneously determined, for the municipality's decision to privatise or not depends on *ACCESS*. We posit that its decision also depends on the variable *LOSSES*, defined as the percentage of losses in water distribution. We therefore use *LOSSES* as well as its lag as instruments. The reason for *NUMCONNECT* to be endogenous is that it is correlated with real prices, which is also an element of the error term. We use the variable *RESIDENTIALSHARE* and its lag as instruments for *NUMCONNECT*.¹³

In order to apply the Hausman-Taylor approach, we need some extra time-invariant exogenous variables to use as instruments. We chose to create the following location dummy variables: *DNORTH*, *DMIDWEST*, *DNORTHEAST*, *DSOUTHEAST* and *DSOUTH*. They take value 1 when the municipality is located in the north, midwest, northeast, southeast or south regions of Brazil, respectively, and zero otherwise. One of them is dropped to avoid collinearity.

For each approach, we estimate two types of model. The parsimonious model is just equation (1) (with the additional dummy variables for Hausman-Taylor). The full model includes dummy variables to take account of the effects of private provision by GDP per capita deciles. There are dummy variables for each GDP per capita deciles, called *DGDP₁* to *DGDP₁₀*, and interaction dummy variables defined as:

$$DPRIVGDP_k = DPRIV * DGDP_k, \quad k = 1, \dots, 10.$$

¹¹ Test results can be found in the appendix.

¹² Hausman and Taylor (1981).

¹³ We actually started out with a larger number of instruments, but settled on those four after performing a series of tests for overidentifying restrictions (validity of instruments) and weak instruments.

We first discuss the results of the parsimonious model, presented below. The dependent variable is the log of *ACCESS* instead of *ACCESS*. This improves the fit of our regressions.

Table 3: Estimation of Parsimonious Model of Impact of Private Provision on Access to Water by EC2SLS and Hausman-Taylor

Explanatory variables	EC2SLS	Hausman-Taylor
<i>DPRIV</i>	0.3640126 (0.000)	0.4880258 (0.00)
<i>NUMCONNECT</i>	2.57e-06 (0.000)	7.45e-07 (0.000)
<i>DMIDWEST</i>	—	0.7562558 (0.000)
<i>DNORTHEAT</i>	—	0.3789178 (0.000)
<i>DSOUTHEAST</i>	—	0.6856104 (0.000)
<i>DSOUTH</i>	—	0.4730724 (0.000)
<i>D2002</i>	0.0387334 (0.000)	0.0061266 (0.729)
<i>D2003</i>	0.0067238 (0.432)	0.0265774 (0.134)
<i>D2004</i>	0.0208469 (0.009)	0.049163 (0.006)
<i>D2005</i>	0.0241538 (0.162)	0.0654037 (0.000)
<i>D2006</i>	0.0167523 (0.336)	0.0479276 (0.007)
<i>D2007</i>	0.0153829 (0.030)	0.0557278 (0.002)

Table 3: Estimation of Parsimonious Model of Impact of Private Provision on Access to Water by EC2SLS and Hausman-Taylor: Continues

Explanatory variables	EC2SLS	Hausman-Taylor
<i>D2008</i>	Omitted	0.0426003 (0.019)
<i>DENSITY</i>	0.1425712 (0.011)	0.1082461 (0.011)
<i>EXCONNECT</i>	0.001336 (0.052)	-0.0004453 (0.440)
<i>INVEST</i>	-1.08e-09 (0.151)	-8.67e-10 (0.192)
<i>PRODUCTIVITY</i>	- 0.0053421 (0.000)	-0.0120178 (0.000)
<i>GDPPERCAP</i>	3.39e-06 (0.000)	2.52e-06 (0.000)
<i>CONSTANT</i>	3.86274 (0.000)	3.463448 (0.000)
Prob > χ^2	0.000	0.000
R^2 (overall)	0.0899	
Number of observations	7796	9673

Note: Each column reports the estimated coefficients of the regression of the dependent variable LACCESS on the explanatory variables. P-values are in parentheses.

The two methods produce very similar qualitative results. All the continuous explanatory variables with the exception of *INVEST* (and *EXCONNECT* in the Hausman-Taylor estimation) are significant and their coefficients have the same sign across the two estimations. Most of the time dummies are significant, as are all the location dummies in the Hausman-Taylor model. That is evidence that our choice of dummy variables was appropriate.

Although our main interest falls on the dummy variable *DPRIV*, let's comment briefly on the signs of the other explanatory variables. *DENSITY* has a positive coefficient, as expected, indicating that economies of density tend to increase access to water service. *NUMCONNECT* has a positive coefficient, which is also in line with expectations, since larger numbers of water connections are associated with economies of scale. The coefficient of *EXCONNECT*, however,

is surprising. Higher values of the extension of the water system by water connection usually reflect higher costs to provide access, and that should lead to lower access rates. Even though this coefficient is statistically significant, it is relatively small. The negative sign of the variable *PRODUCTIVITY* indicates that more efficient companies are associated with larger access rates. Finally, *GDPPERCAP* has a positive impact on access rates, meaning that richer municipalities are likely to have higher water service coverage. These two last effects are also in line with expectations.

The most important effect measured by the estimations above is that of private provision on access to water service, as measured by the coefficient of the dummy variable *DPRIV*. According to the estimation of the first model, private provision increases the access rate by approximately 36.4 percent when the other explanatory variables are held constant. That impact increases to approximately 48.8 percent when the Hausman-Taylor approach is used. That is a very strong effect. Even if the absolute values of the coefficients seem to be excessive, the important result is that there is strong evidence that private provision increases access to water service in Brazil.

The next question is whether this impact differs by income decile. Since we don't have information on income by municipality, we use GDP per capita deciles instead. The results of the full model, presented below, help us answer that question.

Table 4: Estimation of Full Model of Impact of Private Provision on Access to Water by EC2SLS and Hausman-Taylor

Explanatory variables	EC2SLS	Hausman-Taylor
<i>DPRIV</i>	0.3381967 (0.000)	0.2254604 (0.000)
<i>NUMCONNECT</i>	1.68e-06 (0.000)	7.65e-07 (0.000)
<i>DMIDWEST</i>	—	0.6472151 (0.000)
<i>DNORTHEAST</i>	—	0.3344953 (0.000)
<i>DSOUTHEAST</i>	—	0.5762625 (0.000)
<i>DSOUTH</i>	—	0.3807556 (0.000)
<i>D2002</i>	0.099125 (0.000)	0.0058275 (0.742)
<i>D2003</i>	0.0877945 (0.000)	0.009703 (0.587)

Table 4: Estimation of Full Model of Impact of Private Provision on Access to Water by EC2SLS and Hausman-Taylor: Continues

Explanatory variables	EC2SLS	Hausman-Taylor
<i>D2004</i>	0.0924273 (0.000)	0.0249712 (0.168)
<i>D2005</i>	0.0895158 (0.000)	-0.035422 (0.053)
<i>D2006</i>	0.0516072 (0.000)	-0.0124199 (0.505)
<i>D2007</i>	0.0305306 (0.005)	0.0103931 (0.589)
<i>D2008</i>	Omitted	-0.0105006 (0.595)
<i>DGDP₂</i>	0.0702999 (0.000)	-0.0297023 (0.013)
<i>DGDP₃</i>	0.1844806 (0.000)	-0.0262618 (0.000)
<i>DGDP₄</i>	0.2642057 (0.000)	0.0148674 (0.397)
<i>DGDP₅</i>	0.3177737 (0.000)	0.0353318 (0.074)
<i>DGDP₆</i>	0.3872484 (0.000)	0.0737202 (0.001)
<i>DGDP₇</i>	0.4452334 (0.000)	0.0989576 (0.000)
<i>DGDP₈</i>	0.4896014 (0.000)	0.1207793 (0.000)
<i>DGDP₉</i>	0.5607896 (0.000)	0.1402619 (0.000)

Table 4: Estimation of Full Model of Impact of Private Provision on Access to Water by EC2SLS and Hausman-Taylor: Continues

Explanatory variables	EC2SLS	Hausman-Taylor
<i>DGDP</i> ₁₀	0.6005758 (0.000)	0.1575338 (0.000)
<i>DPRIVGDP</i> ₂	-0.0615855 (0.503)	0.0913524 (0.057)
<i>DPRIVGDP</i> ₃	-0.1373686 (0.113)	0.1042035 (0.028)
<i>DPRIVGDP</i> ₄	-0.124582 (0.152)	0.1259194 (0.009)
<i>DPRIVGDP</i> ₅	-0.1325435 (0.138)	0.1615181 (0.001)
<i>DPRIVGDP</i> ₆	-0.1638199 (0.069)	0.1482877 (0.004)
<i>DPRIVGDP</i> ₇	-0.1980223 (0.028)	0.1374668 (0.009)
<i>DPRIVGDP</i> ₈	-0.1962635 (0.031)	0.1275632 (0.017)
<i>DPRIVGDP</i> ₉	-0.2702937 (0.003)	0.1093693 (0.048)
<i>DPRIVGDP</i> ₁₀	-0.2565348 (0.007)	0.1397871 (0.020)
<i>DENSITY</i>	.0844096 (0.102)	0.088384 (0.039)
<i>EXCONNECT</i>	-0.0053897 (0.000)	-0.0003781 (0.510)
<i>INVEST</i>	-1.54e-09 (0.182)	-7.04e-10 (0.286)
<i>PRODUCTIVITY</i>	-0.0163476 (0.000)	-0.0122305 (0.000)

Table 4: Estimation of Full Model of Impact of Private Provision on Access to Water by EC2SLS and Hausman-Taylor: Continues

Explanatory variables	EC2SLS	Hausman-Taylor
<i>GDPPERCAP</i>	4.56e-07 (0.416)	1.85e-06 (0.000)
<i>CONSTANT</i>	3.723861 (0.000)	3.547776 (0.000)
Prob > χ^2	0.000	0.000
R^2 (overall)	0.2500	
Number of observations	7796	9673

Note: Each column reports the estimated coefficients of the regression of the dependent variable *LACCESS* on the explanatory variables. P-values are in parentheses.

The coefficients of the continuous explanatory variables keep the same signs as in the previous estimations, with the exception of *EXCONNECT*, which now has the expected negative sign (although it is not significant in the Hausman-Taylor model).

More importantly, the coefficient of *DPRIV* is positive and significant in both regressions. The impact of private provision on access rates is approximately 33.8 percent according to EC2SLS, and 22.5 percent according to Hausman-Taylor.

All of the GDP decile dummy variables are significant in EC2SLS, and some of them in Hausman-Taylor. Notice that the higher deciles display the largest coefficients, as expected. This means that municipalities in higher deciles have higher access rates. For instance, municipalities in the highest (tenth) decile have access rates approximately 53 percent (0.6005758 – 0.0702999) higher than those in the second decile.

As for the interaction dummies, there is a clear distinction between the EC2SLS and Hausman-Taylor results. In the former, all of the coefficients are negative but those for the lower deciles (up to the fifth) are not significant. In contrast, all the corresponding Hausman-Taylor coefficients are positive and significant. The table below lists the different impacts of private provision of water services by GDP per capita decile according to the two methods.

Table 5: Impact of Private Provision of Water Service by GDP Per Capita Decile

Decile	Percentage increase in <i>ACCESS</i>	
	EC2SLS	Hausman-Taylor
2 nd	-	31.68
3 rd	-	32.97

Table 5: Impact of Private Provision of Water Service by GDP Per Capita Decile: Continues

Decile	Percentage increase in <i>ACCESS</i>	
	EC2SLS	Hausman-Taylor
4 th	--	35.14
5 th	--	38.70
6 th	17.44	37.37
7 th	14.02	36.29
8 th	14.19	35.30
9 th	6.79	33.48
10 th	8.17	36.52

The table should be read as follows: According to EC2SLS, for instance, municipalities with private provision of water service belonging to the 6th decile of GDP per capita, have, on average, access rates 17.44 percent higher than those in the same decile but with public provision. The Hausman-Taylor numbers are significantly higher, but notice how the impact of private provision on access to water service tends to diminish after the 5th decile.

B. Estimation Using the HAD Dataset

In the models estimated in the previous section, we made no attempt to account for a possible "inertia" effect, i.e., to reckon that access rates in one period are highly dependent on access rates in the previous period. Panel data models with lagged dependent variables should be estimated by conditional maximum likelihood, and several identification and computational issues would have to be addressed. Moreover, the inclusion of lagged *ACCESS* as an explanatory variable would likely blur the effects of the other explanatory variables. We chose instead to use a different dataset to compare the situation of municipalities in terms of access rates before and after the beginning of the privatizations of water supply.

The database used in this new wave of regressions comes from the Brazil Human Development Atlas (HAD), a publication of the United Nations Development Programme in Brazil. This database consolidates data available in the 1991 and 2000 Brazilian Demographic Censuses published by IBGE.

The objective of the second set of regressions is again to identify the average effect of private provision on access to water supply. Ideally, this would be done by comparing access rates when water services are privately provided to the counterfactual, namely access rates when services are publicly provided in the treatment (subject to private provision) areas at the same point in time. Of course, this counterfactual is not observed, and we need to resort to estimation methods. The first choice would be to conduct an experiment where private and public management are randomly assigned to municipalities and then compare the average outcomes of

the two groups. Once again, that choice is not available to us, for the decision to privatize water services is hardly random. There is the possibility then that municipalities that choose to privatize are different along some dimensions from those that choose not to privatize and that these differences are correlated with access.

This concern will always be present in our non-experimental estimations, but we will try and minimize it by controlling for time-invariant unobserved effects. This will be done by using a panel data and a difference-in-differences estimator. In that respect, we follow Galiani et al. (2005) and Fujiwara (2004), who use this method to assess the impact of privatization on infant mortality rates.

The difference-in-differences method amounts to comparing the change in outcomes in the treatment group before and after the treatment (in our case, privatization) is applied to the change in outcomes in the control group (in our case, the set of municipalities which did not privatize their water services). By comparing changes, it is possible to isolate the effects of treatment from other factors affecting the outcome.

As is well known (see, for instance, Wooldridge (2002)), the difference-in-differences estimator can be obtained by running a fixed effects panel data regression. We follow that procedure here. The dependent variable is again *ACCESS*, but this time defined as the percentage of the population living in households with access to piped water. The explanatory variables are *DPRIV*, defined as before, *INCPERCAP*, the per capita income of the municipality, *GINI*, the Gini index, *POVERTY*, a poverty intensity index, and *RURALPOPPERC*, the percentage of the population of the municipality living in rural areas. The estimation results can be found in the table below¹⁴:

Table 6: Estimation of Impact of Private Provision on Access to Water Using Difference-in-Differences Approach

Explanatory variables	Fixed effects
<i>DPRIV</i>	6.30713 (0.000)
<i>INCPERCAP</i>	0.07417 (0.000)
<i>GINI</i>	72.82137 (0.000)
<i>POVERTY</i>	-0.61558 (0.000)
<i>RURALPOPPERC</i>	-38.10226 (0.000)
<i>CONSTANT</i>	57.21342 (0.000)

¹⁴ The regression using *ACCESS* as dependent variable instead of *LACCESS* provided a better fit.

Table 6: Estimation of Impact of Private Provision on Access to Water Using Difference-in-Difference Approach: Continues

Explanatory variables	Fixed effects
Prob > F	0.000
R^2 (overall)	0.6256
Number of observations	11,014

Note: Each column reports the estimated coefficients of the regression of the dependent variable *ACCESS* on the explanatory variables. P-values are in parentheses.

The model provides a good fit to the data, as confirmed by the significance of all the coefficients. The signs of the coefficients of the explanatory variables are consistent with our *ex ante* expectations. Higher access rates are associated with higher income per capita and lower poverty indices. The percentage of the population living in rural areas has a negative effect on access, indicating that municipalities with large rural populations should be targets for universal service policies. As for the effect of the Gini index of inequality on access, positive according to our estimations, one plausible explanation is that municipalities where there is more inequality are relatively large metropolitan areas where coverage is high due to the existence of economies of scale.

But our main concern here is with the variable *DPRIV*, which measures the effect of private provision on access rates. Just as in our previous estimations, we get a positive and significant estimated coefficient, confirming the positive impact of privatization on access by the population to water services. Given the already relatively high coverage rates of the higher income deciles of the Brazilian population, it is fair to say that the benefits of such increased access rates due to private provision accrue mostly to lower income families.

V. Discussion of Results and Policy Recommendations

There is no evidence in the results we obtained to support the argument that private sector water supply in Brazil, still a limited experience, has had an adverse impact on affordability or access. On the contrary, we obtained evidence that there was an improvement in access as a result of PSP and that this effect was more pronounced in municipalities at the bottom of the income (GDP) per capita spectrum. These results allow us to conjecture that low income households have benefited the most in that respect, since Brazil has a relatively high coverage rate in water provision (in comparison to other developing countries) and higher income families are usually the first to be covered.

Even though the econometric analysis does not bear it out (the variable *INVEST* is not very reliable and is likely measured with error), one possible explanation for our results is that they are a consequence of investment obligations agreed to by private operators at the time they were granted concessions. Total scheduled investments by private operators until the end of their concession contracts (between 2025 and 2030) amounts to R\$3.38 billions (approximately

US\$1.54 billion), of which R\$1.10 billion (approximately US\$500 million) or 32,7 percent had been disbursed until the end of 2004. Disbursements until the end of 2009 are estimated at half the total value of investments.

The table and figures below show that, despite displaying lower investments than publicly-owned or managed companies on average,¹⁵ privately-owned or managed companies beat their public counterparts in all size categories in that respect.

Table 7: Investments by Type and Size of Operator

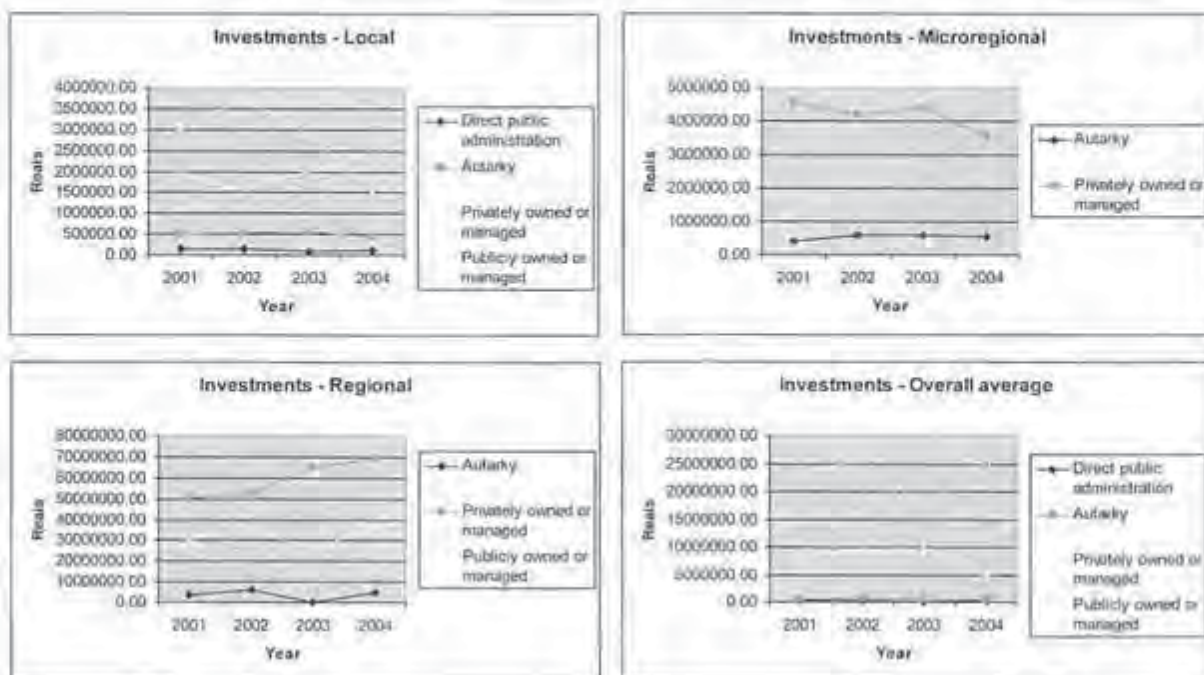
	2001	2002	2003	2004
Direct public administration				
Local	136453.49	143025.42	103051.10	111429.17
Microregional	–	–	–	–
Regional	–	–	–	–
Autarky				
Local	532386.30	557997.06	547126.94	457645.92
Microregional	513055.39	521468.55	548444.20	434981.40
Regional	405257.85	602674.69	608623.33	541248.61
Privately-owned company or public company with private management				
Local	3454309.86	5785506.69	5174.13	4792124.56
Microregional	8480585.47	9251176.07	9686443.71	5560120.69
Regional	3041880.35	3725373.26	2876372.75	1516335.76
Publicly-owned company or public company with public management				
Local	4537491.10	4189316.61	4408820.93	3548444.67
Microregional	50494615.71	52993855.18	65273374.62	69234408.74
Regional	23075693.54	25684752.22	17500182.89	25234027.12
Local	1950978.61	1587030.93	2007809.76	2431744.95
Microregional	–	–	–	–
Regional	30757408.07	35542910.92	25246389.46	37178079.69

Source: PMSS – National Sanitation Information System (SNIS).

Note: Local operators are those that provide water services only to the municipality where they are located. Microregional operators are those providing services to more than one municipality, normally a small number of them and adjacent to each other, including intermunicipal consortia. Regional providers are those that serve several municipalities and includes the CESB's (state companies).

¹⁵ This result is due to the fact that there are no microregional publicly-owned or managed companies, which props up their average

Figure 4: Investments by Type and Size of Operator



In summary, there is evidence that greater presence of private undertakings in the Brazilian water sector can be beneficial, not only because the sector has a great demand for investments which cannot come entirely from the public sector, but also because private provision can improve access to the poor without imposing an excessive financial burden on them.

There are several policy recommendations that stem from this conclusion. First, the federal government should consider using the tools at its disposal to incentivize greater private participation in water supply at the local level. For instance, it could make subsidized loans or other resources available to local governments that were willing to create public/private partnerships (PPPs) or franchise water supply. It could also direct the Brazilian Development Bank (BNDES) to offer financial support mechanisms to private companies that are either already in the water supply business or are planning the acquisition of assets in that sector.

Both federal and local governments should also review and possibly develop new regulations to facilitate the entry of private companies into the water supply industry and at the same time give them incentives to be efficient and share productivity gains with consumers. Even though water supply has natural monopoly features and its technology doesn't change fast, characteristics that are usually associated with rate of return regulation, fiddling with incentive regulation (e.g. price-cap) can be fruitful. It is well documented that the adoption of price-cap regulation in sectors such as electricity and telecommunications has typically generated efficiency gains.

The potential greater participation of the private sector in water supply (and possibly other sanitation services) would have a wider social impact if it were accompanied by other measures. For instance, it could be made to serve poor customers by placing emphasis on tariff design, so that low income families were targeted more accurately. Political, social and cultural institutions or norms to monitor the private sector could be furthered. Right now they are almost non-existent in Brazil. Municipalities and state agencies are the only entities responsible for enforcing

concession contracts. And finally, universal service obligations, currently absent from most concession contracts, could be negotiated with or even imposed on private providers.

Finally, the policy implications of our results are not constrained to Brazil. In most developing countries, and even in advanced economies, the public sector might not have the ability or the willingness to increase capacity or tweak the system to increase efficiency and reduce costs. Given the positive externalities of adequate water supply, it is clearly worth entertaining the possibility of expanding private provision, as long as it is accompanied by effective regulation.

VI. Conclusion

The provision of water and sewage services in Brazil is by and large very deficient. As we discussed in this paper, the main problems can be found in rural areas and the poorest regions of the country, which usually display lower access rates and pay disproportionately more for water service. The poorer households also have difficulties accessing and paying for water.

Nevertheless, there have been some improvements as of lately. That can be at least partially attributed to government investment and social policies implemented in the sector. Those policies have been structured mostly in the form of stand-alone programs managed by different ministries. The main objective of most of those projects is to increase production capacity and coverage of water supply. Some of them have targeted initiatives aimed at increasing water supply and sewage services for low-income families, while others were tailored to increase coverage and improve quality of service in rural areas. There has been relative success in that area, and coverage rates for the lowest three deciles have increased. This is indication that the poor have benefited from social policies put in place in the sector. In spite of the relative success of social policies in reducing inequality, the distribution of access across income classes continues to be very uneven in Brazil.

Private sector participation can be a way to increase coverage and improve the distribution of access to water services. As a matter of fact, we were able to show that private operators have outperformed their public counterparts in that respect. We can thus conjecture that low income households have benefited the most from PSP, since Brazil has a relatively high coverage rate in water provision (when compared to other developing countries) and higher income families are already covered. A possibility worth investigating is if part of this result can be attributed to investment obligations assumed by private operators at the time they were granted their concessions.

The policy implications of our results are significant. Different levels of government, both in Brazil and in other countries where water is not universally supplied, should develop financial, regulatory and budgetary tools that can help further private participation in the water supply sector. Where the government is in no position to provide the service, privatization may be the solution. Where the government wants to keep playing an important role, public/private partnerships should be considered. Given the natural monopoly characteristics of the water sector, though, it is paramount that those initiatives be supplemented with appropriate regulatory measures that keep in check the company's market power.

In summary, the evidence and econometric results we brought forth support the case for greater presence of private undertakings in the water sector (and perhaps the sanitation sector in general) in developing countries, not only because the sector has a great demand for investments

which cannot come entirely from the public sector, but also because private provision tends to improve access to the poor without imposing an excessive financial burden on them.

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Appendix I

Hausman test results:

. hausman FE RE, sigmamore

	--- Coefficients ---			
	(b) FE	(B) RE	(b-B) Difference	sqrt (diag (V_b-V_B)) S.E.
dpriv	.1507247	.16364	-.0129153	.0858399
numconnect	1.73e-06	9.27e-07	8.07e-07	5.89e-07
d2002	.0049796	-.0064878	.0114674	.0020086
d2003	.0257097	.0132017	.012508	.0022623
d2004	.0479465	.0349182	.0130283	.0025097
d2005	.0638646	.0499921	.0138725	.002724
d2006	.0458417	.0316951	.0141466	.0029734
d2007	.05413	.037875	.016255	.0035058
d2008	.0410245	.0256699	.0153545	.0038988
density	.0226113	.1901539	-.1675426	.0288679
exconnect	-.0000404	-.0004259	.0003855	.0002269
investment	-.1.24e-09	-9.98e-10	-2.46e-10	3.02e-10
productivity	-.0115457	-.0129014	.0013557	.0001355
gdppercap	2.12e-06	3.39e-06	-1.27e-06	2.69e-07

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

$$\begin{aligned} \text{chi2 (11)} &= (b-B)' [(V_b-V_B)^{-1}] (b-B) \\ &= 216.31 \\ \text{Prob>chi2} &= 0.0000 \\ (V_b-V_B \text{ is not positive definite}) \end{aligned}$$