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Regulation and performance: A production frontier estimate for the Latin American water and sanitation sector

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ABSTRACT

The objective of this paper is to analyze the efficiency of the water sector in Latin American countries. We try to find factors affecting efficiency rather than identifying which country or individual provider is more or less efficient. We also consider which model would be more fitting for the water sector production in this region. Our motivation is to develop instruments to make benchmarking operative for regulatory actions that can reduce information asymmetry and increase efficiency in Latin American countries. We estimate econometric efficiency frontiers using data from a regional survey conducted by the Latin American Association of Water Regulators. The paper develops a model based on the core variables that explain the phenomena and explores "environmental" (contextual or beyond management control) variables to achieve fair comparisons. The study does not "name and shame" services but provides elements to foster the development of indicative goals at the regional level.

1. Introduction

One of the goals of public utility regulation is to ensure that present and future consumers have access to services with efficient provision, high product and service quality, and reasonable tariffs. Efficiency comparisons are central to tariff revisions. Benchmarking studies are generally commissioned by regulators, as well as by firms, to estimate relative efficiency or productivity changes. They are crucial to mitigating information asymmetry and to determining the X factor that affects prices during the tariff period.

The regulatory use of the results of these kinds of studies could follow a more ambitious or a more limited approach, for instance, using efficiency or productivity estimates to discuss tariffs and performance goals.[1] Hargreaves et al. (2006) summarize their use in England and Wales to set the X factor in the pricing formula. This more rigorous application is called "yardstick competition". A lighter approach, the so-called "sunshine competition" applied in the Netherlands, seeks to evidence the best practices through "naming and shaming" (inefficient) providers (De Witte and Dijkgraaf, 2007). Another though more modest approach is to reach a consensus on some floor performance standards in order to emulate other realities.

"Yardstick competition" has been introduced in countries with private provision to replicate competition incentives. In countries with public provision, "sunshine competition" has been advanced as a means to provide good incentives to providers. In any case, a benchmarking activity in the utility context is one way to provide competitive incentives in a monopolistic market.

The way in which the benchmarking is established in the Netherlands does not imply an expensive structure. It leaves all the decisions of products and service performance up to the provider, including the definition and control of minimum standards. Annual data gathering yields exhaustive information about costs, quality and levels of service, in addition to comparing providers via performance indicators. The information is elaborated at different company levels, at process (production, distribution, sales, and the management), and at subprocess levels (such as the cost of 1 m of pipes or the cost of installing a meter) inside and outside the providers. (De Witte and Dijkgraaf, 2007).

Comparative studies at an aggregate level indicate which services are weak in terms of efficiency and leave it up to the managers to decide where and when the improvements have to be implemented. Our motivation is to develop instruments to make benchmarking operative for regulatory actions addressing asymmetric information issues in Latin American countries. From a global perspective, Latin America could be situated at an

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[1] In an extreme case, it could be used to set the X-Factor directly (Bernstein and Sappington, 1999).

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intermediate level in terms of coverage, quality and cost recovery through tariff collection.

The objective of this paper is to analyze the efficiency of the water sector in Latin American countries. We try to find factors affecting efficiency rather than identifying which country or individual provider is more or less efficient. We also try to identify a fitting model for water sector production in this region.

We use econometric methods (Stochastic Frontier Analysis, SFA) to estimate the relative efficiency of water and sanitation providers in Latin America in the period 2003/2008. We develop a model based on the core variables that explain the phenomena. We also explore "environmental" (contextual or beyond management control) variables[2] to achieve fair comparisons. The study does not "name and shame" services but provides elements to foster the development of indicative goals at the regional level.

This paper contributes to the empirical discussion, as well as offering some considerations on suitable variables to include and the functional form that would better characterize the productive technology. The estimates require the simultaneous analysis of variables to be included and the relevant functional forms. We identify inputs and outputs and some environmental variables that could characterize the regional water sector. In other sectors where previous studies of this type have been conducted, such as electricity, a consensus exists on both aspects.

The database was based on a survey conducted by the Latin American Association of Water Regulators (ADERASA) – an organization comprising 16 Latin American countries. The response to the successive surveys was voluntary and the quality of the responses from the providers increased. Over time we developed studies with earlier waves of the survey but only cross-section estimates have been made to date, highlighting their potential when designing regional standards for comparisons and improving performance (Romero, 2005; Ferro and Romero, 2007a,b,c, 2009). In this paper, we go one step further using a panel instead of a cross-section database.

Following this introduction, Section 2 makes a brief review of the literature on econometric estimates of efficiency frontiers in the international water and sanitation sector and discusses the previous work in the region. Section 3 presents the descriptive statistics of the database. Section 4 estimates the frontier and we discuss the results in Section 5. Finally, Section 6 concludes.

2. A review of the literature

This review discusses the methodology and variables included in previous efficiency studies that use econometric methods. It highlights aspects that are relevant to the modeling process and the sector under study. We also summarize extra-regional studies.

The literature has grown and become increasingly more complex over time. An analysis of the variables reveals that the output is approximated either by water production volume or by clients. The capital and labor inputs are approximated by means of network length and full-time staff, respectively. Unit labor cost is usually a proxy for the average of the salaries paid to full-time staff. The cost of the capital input is measured frequently by non-labor costs divided by the network length.

The literature does not fully concur on the environmental variables. It is often assumed that certain variables improve productivity (or reduce costs). For instance, two commonly used variables are the geographic concentration of the clients and the proportion of metered clients. We can see ambiguous results in "unaccounted for water", depending on whether the losses are billed to clients. Many providers bill water losses to clients, offering no incentives to control leakages. Larger losses are associated with lower water pressure, frequent service interruptions and low overall quality levels. Decision units in our sample (that is, providers) fall within different regulatory and institutional frames. In this study, we try to determine whether those differences affect efficiency estimates.

In the Latin American context, we identify four groups of studies referring to water and sanitation efficiency frontiers: 1) studies generated in Brazil, 2) those developed in the Public Utility Research Center (PURC) of the University of Florida at Gainesville (which comprise studies on the Caribbean, Central America, Peru, and Brazil), 3) the estimates by the Centro de Estudios Económicos de la Regulación (CEER) of the Universidad Argentina de la Empresa (UADE) in Buenos Aires, and 4) the studies commissioned by ADERASA.

In the case of Brazil, Motta and Moreira (2004) examine efficiency in the sanitation sector; Tupper and Resende (2004) analyze related efficiency and regulatory issues; Moreira and Fonseca (2005) compare productivity measures based on mathematical programming and stochastic frontiers; and Da Silva e Souza et al. (2007) estimate a stochastic cost frontier for private and public water companies.

Of the group of studies carried out by the PURC, Corton (2003) examines the comparative efficiency of the water and sanitation enterprises in Peru; Mobbs and Glennie (2004) work on DEA using the first ADERASA survey database; Lin (2005) analyzes Peru's quality of service; Lin and Berg (2008) study consistency between methodologies in Peru; Sabbioni (2005), (2008) estimates econometric frontiers in the sanitation sector in Brazil; Berg (2006) examines the different benchmarking approaches; Berg (2007) studies the conflict resolution for the water and sanitation providers' performance; Berg and Corton (2007) analyze the efficacy of the benchmarking techniques for less developed countries; Corton and Berg (2008) apply benchmarking techniques to study the Central American water industry; Marques and Berg (2010) develop a "meta-study" on the empirical literature in the water sector performance studies; and Berg (2010) synthesizes the techniques and findings of different authors in an interesting and very didactic text.

At CEER, numerous studies were conducted on comparative efficiency in other infrastructure sectors in the 1990s. In the water sector we can mention Ferro (1999) on partial indicators, Ferro (2007) on econometric frontiers, and Ferro and Romero (2007b) who survey the literature on efficiency frontier use in the sector. Ferro and Romero (2008) estimate a cost function for many Latin American countries with a cross-section database.

The above three references are academic papers which use a common source of data for the estimates: ADERASA's, containing information from more than one hundred providers in 16 countries. In addition to the preceding database "Sistema Nacional de Informações sobre Saneamento" (SNIS) from Brazil, ADERASA's survey is a rich source for regional studies and its database offers valuable information to build partial productivity indicators, average costs, regulatory accountancy, quality, and so on. Its progressive improvement allows for data consistency and comparison. ADERASA commissioned three studies with different versions of the database: Romero (2005) makes an exploratory approach with the first wave of the survey using data from 2003 until 2008; Ferro and Romero (2007a) provide estimates made with DEA and econometric techniques for the 2005 survey; and Ferro and Romero (2009) develop a panel study with DEA and econometrics for the accumulated data from 2003 to 2008.

[2] These variables could be employed to design characteristics which differentiate the operational environment, regulatory demands (regarding quality), geography, distribution conditions (sparse or concentrated), the weather, the state of the network, among others.

Finally, in the region under study we should highlight the publication of sectoral indicators for management and comparative benchmarking by the Peruvian water regulator, SUNASS, the DEA approach used in Colombia for tariff calculation by the Colombian sectoral regulator, CRA, and the above-mentioned SNIS with data from more than 500 providers in Brazil.

Outside of the Latin American region each article differs on the aspects under study. We reviewed Fox and Hofler (1986) who estimate both production and cost frontiers for the US; Lynk (1993) estimates a cost function for Britain; Bhattacharyya et al. (1995a), (1995b) do the same for the US; Cubbins and Tzanidakis (1998) focus on the United Kingdom; Antonioli and Filipini (2001) study Italian companies; Estache and Rossi (2002) estimate efficiency for Asia and the Pacific region; Estache and Kouassi (2002) do the same for Africa; Bottaso and Conti (2003) compare efficiency for the English and Welsh water industry during the pre-privatization and post-privatization periods; Aubert and Reynaud (2005) measure efficiency in the US; Fraquelli and Moiso (2005) estimate efficiency frontiers for Italy; Kirkpatrick et al. (2006) study Africa; Mugisha (2007) assess efficiency in Uganda; Walter et al. (2009) offer a comprehensive survey of the literature and group the studies by their motivation. It classifies the papers under: 1) selected studies evaluating the effect of ownership; 2) studies evaluating the impact of structural and quantity variables with a focus on DEA; 3) studies estimating economies of scale and scope; and 4) studies estimating economies of scope for electricity, gas, and water provision.

3. The database

The database is an unbalanced panel including information on 16 Latin American countries −Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay and Venezuela − between the years 2003 and 2008. It was built from a very ample survey although its quality was not completely homogeneous or reliable. We made a detailed study of each observation and used a subset of the variables and of the information to perform our analysis. The physical information was more dependable (and also comparable between countries) than the monetary data, which exhibit some variability between observations and between the years.

Table 1 presents the complete information by country and by year. There are 482 observations from 188 different providers, not all of whom responded every year; in many cases we lacked information about all of the variables from the same provider.

Table 1
Observations (by country and year).

Country	2003	2004	2005	2006	2007	2008	Total
Argentina	8	7	7	7	7	5	41
Bolivia	2	1	2	0	0	0	5
Brazil	9	9	0	6	8	4	36
Chile	17	17	17	17	18	17	103
Colombia	0	5	33	37	38	38	151
Costa Rica	1	2	2	2	2	2	11
Ecuador	1	1	1	1	1	1	6
El Salvador	0	0	0	1	0	0	1
Honduras	1	1	1	1	1	1	6
Mexico	0	0	9	3	2	1	15
Nicaragua	1	1	1	0	0	0	3
Panama	1	1	1	1	1	1	6
Paraguay	0	1	1	4	4	4	14
Peru	9	9	10	10	10	9	57
Uruguay	0	0	1	1	1	1	4
Venezuela	0	0	0	3	11	9	23
Total	67	64	125	96	111	38	482

Source: Own Elaboration.

Nicaraguan and Venezuelan providers were dropped from the final sample because of missing information on key data.

The description of the variables used in the efficiency estimates is presented in Table 2. From those variables we could build transformations, such as ratios, percentages and dummies, to evaluate environmental, qualitative or hedonic features in particular. We also present a descriptive statistic of all the variables in use, which account for each one's magnitude and for a landscape of the sector considering country differences and the lack of information in some years.

The average unit of the sample dispatches 375,000 cubic meters of water daily, employs 739 full-time workers, and meters 75% of the clients. It has a distribution network of 2658 km of pipes with a density of 481 inhabitants per kilometer of network. Its water losses represent 41% of total dispatched water.

4. Frontier estimates

Two sides of the modeling process need to be identified: 1) the search for the economic model, that is, the selection of the functional form and variables; and 2) the estimation procedure, which is the selection of the estimator.

4.1. Economic model

The database includes cost data that serve to infer the input prices. However, the quality of the data is not satisfactory enough, as in the case of physical variables, which, in turn, make better country comparisons possible. Hence, we analyzed different relationships between variables and found some unexplained inconsistencies between monetary and physical variables, where the latter exhibit a more predictable behavior.

The relationship to estimate departs from:

Output = f (inputs)

We try two functional forms as alternative representations of the production function: a Cobb-Douglas and a translogarithmic technology. The Cobb-Douglas specification in logarithms is:

$$\ln Y = \ln\beta_0 + \sum_{n=1}^{N} \beta_n \ln X_n$$

Where Y is the output and X represents the input vector. In every case, β denotes the estimated parameters.

The translogarithmic specification is:

$$\ln Y = \ln\beta_0 + \sum_{n=1}^{N} \beta_n \ln X_n + \frac{1}{2}\sum_{n=1}^{N}\sum_{m=1}^{N} \beta_{nm} \ln X_n \ln X_m$$

The notation has the same meaning as in the Cobb-Douglas.

The Cobb-Douglas formula is widespread in the literature because of its simplicity and the easy interpretation of its results. Nevertheless, it imposes unnecessary constraints on production technology. The translog specification is generally considered a quadratic approximation of any arbitrary production function and is also a generalization of the Cobb-Douglas. The translogarithmic function has the advantage of being more flexible than the Cobb-Douglas representation. It does not impose a priori constraints on factor substitution possibilities and variations in the returns to scale with the output level, making it possible to capture the U-shaped unit cost curve. The translog functional form adds interaction terms between the variables, which are not present in a Cobb-Douglas. Its disadvantage is the amount of consumed degrees of freedom in small databases.

We characterize the variables by grouping them into three large sets: outputs, inputs and environmental or institutional variables.

Table 2
Description of the variables.

Variable	Description	Unit	Count	Average	Standard deviation	Minimum	Maximum
Vdis	Volume of dispatched water	000 m3/day	388	375	834	4.05	7717
Cliw	Water clients	000	420	300.8	687	2,68	7865
Empl	Full time staff	N°	420	739.8	1549	17	18,546
Wnet	Water mains length	Km	418	2658	5318	60	57,322
Mete	Operative meters on water clients	Proportion	418	0.75	0.29	0.01	1.00
Dens	Population served with domiciliary water service on total water mains length	inhabitants/km	417	481	232	63	1994
Loss	Water losses on total dispatched water (“unaccounted for water”)	Proportion	340	0.41	0.15	0.005	0.959

Source: Own Elaboration.

Output = f (inputs, environmental and institutional variables)

Outputs in a water production function could be represented by means of dispatched water, clients or connections, or even by covered population. The dispatched water variable is highly correlated with clients in our database (with a correlation coefficient of 0.96). We chose dispatched water as the dependent variable. We did not include the coverage data as we had reservations about their quality.

Inputs include variables such as full-time workers and kilometers of water mains as representations of labor and capital. We did not count with details on the roles of the staff members (such as commercial, operative, administration, etc.).

Finally, we consider environmental and institutional variables. The former are those variables accounting for external factors that could influence the relative performance of the units over which the providers had no control. These included such concepts as different characteristics of geography and location, some properties of the service (whether the service is metered), and other data about client service when available. The institutional variables referred to the type of regulator (specialized or multisector), and, given a sample composed of observations from many countries, we tried to proxy country differences by means of country dummies.

4.2. Estimation procedure

The following discusses the methodology to perform the estimates. The model introduced by Battese and Coelli (see Coelli et al., 2005) assumes that a specific characteristic in each firm (or more generally, “decision unit”) exists and is not subject to measurement:

$$y_{it} = x_{it}\beta + (v_{it} - u_{it}) \quad i = 1,2,\dots,N \; t = 1,2,\dots,T$$

$$u_{it} = u_i \exp(-\eta(t-T))$$

$$v_{it} \overset{iid}{\sim} N\left(0,\sigma_v^2\right); \;\; u_i \overset{iid}{\sim} N\left(0,\sigma_u^2\right)$$

Where the lower case letters x and y represent the logarithms of X and Y and β and η are vectors of parameters to be estimated; the v_{it} are independent of the u_i; the u_{it} should be truncated at zero and distributed $N(\mu,\sigma_u^2)$; t are periods of time.

Technically, the error term in the estimates takes the form:

$$\text{ti}_{it} = v_{it} - u_{it} \;\; i = 1,\dots,N; t = 1,\dots,T$$

where v_{it} are random errors and u_{it} is technical inefficiency.

In contrast, to check whether the technical inefficiency effects are random, we compute the variable

$$\gamma = \frac{\sigma_u^2}{\sigma^2}; \;\; \gamma \in (0;1)$$

$$\sigma^2 = \sigma_v^2 + \sigma_u^2$$

To check whether it is possible to find inefficiency effects, we must test whether γ is equal to zero. If γ is zero, there is no inefficiency effect (u_{it} is eliminated), the error term is totally random, and it is possible to estimate the model consistently using Ordinary Least Squares as deterministic frontier.

In the case of stochastic frontier estimates, technical inefficiency can vary systematically across time (TVD, “time varying decay model”), or it can be constant across time (TI, “time invariant model”). In this sense, if η (in the uit formula) is equal to zero, the model does not depend on time and it is correct to assume a TI model.

Panel data provide two alternative approaches: fixed effects and random effects. Under fixed effects, there is a conjecture that the “decision unit” across time has a non-measurable specific characteristic, which is correlated with the regressors of the specified model. On the other hand, random effects assume that the non-observable characteristic is not correlated with the regressor; instead, it is distributed randomly among the firms.

In any case, we estimate the statistic μ, which is associated with the first and second moment of the error term u_i, that is, the technical inefficiency measure. The former was defined as the degree of average inefficiency of the sample or the average distance to the stochastic frontier estimate. If it is statistically equal to zero, we can infer that we are in the presence of a deterministic frontier and that the inefficiency is a result of “noise” or variables which are totally exogenous to the decision unit.

In TVD-type models, we calculate the time evolution of the inefficiency and, for that purpose, it is important to estimate the parameter η. As was mentioned, if η is equal to zero, the efficiencies are constant across time (there are fixed effects). Instead, if it is greater than zero, the efficiencies are increasing; if it is lower than zero, the efficiencies decrease across time.

Since the variables (with the exception of dummies, percentages or ratios) are expressed in natural logarithms, the estimated coefficients can be interpreted as elasticities.

5. Discussion of the results

In this section we present our findings, together with the explanatory model, the more proper functional forms, and the technologies of estimation which yield the best fit.

Table 3 presents the TVD and TI models under Cobb-Douglas (CD) and translogarithmic (TL) specifications. The output is proxied by the logarithm of the volume of dispatched water (*ln vdis*). The inputs are the logarithm of kilometers of water mains (*ln wnet*) and

Table 3
Stochastic frontier estimates.

Dependent variable: Ln vdis	Estimated coefficients			
Independent variables	TVD–CD	TI–CD	TVD–TL	TI–TL
Ln empl	0.0925021***	0.0892682***	0.292406**	0.3012894**
Ln wnet	0.9090134***	0.9154225***	0.5092996***	0.5008345***
Ln empl square			−0.0256464	−0.0257313
Ln wnet square			0.0261249	0.0278438
Ln empl*Ln wnet			0.0102481	0.0086261
Ln dens	0.5509728***	0.5474459***	0.545576***	0.5426158***
Mete	−0.2618353***	−0.2571047***	−0.2620039***	−0.2588102***
Loss	0.0290499	0.0255311	0.029882	0.0272148
D_Argentina	0.4596714	0.4751018	0.4743735	0.4827718
D_Bolivia	−0.3362622	−0.3248456	−0.3063709	−0.3007587
D_Brazil	−0.0438111	−0.0325298	−0.029537	−0.0236697
D_Chile	0.3424551	0.3449465	0.3593191	0.3569931
D_Colombia	0.1520984	0.1755861	0.1983835	0.2140814
D_Costa Rica	0.5711905*	0.5852141*	0.6329212*	0.6451432*
D_Ecuador	0.7441935**	0.7584958**	0.7923905**	0.8013854**
D_El Salvador	0.2450833	0.2622881	0.3563256	0.369058
D_Honduras	0.9902324**	1.026612**	0.916832**	0.939117**
D_Mexico	0.0098679	0.0271516	0.0644538	0.076110
D_Panama	0.9637726**	0.9522656**	1.042537***	1.035311***
D_Paraguay	−0.1217085	−0.1043582	−0.075368	−0.0630099
D_Peru	−0.0596902	−0.0468178	−0.0017172	0.0053407
D_Uruguay	(omitted)	(omitted)	(omitted)	(omitted)
D_Multisectoral regulator	−0.0948525	−0.0929445	−0.0927106	−0.0910589
Constant	2.421667***	2.431262***	3.106300***	3.125565***
mu	0.9132316***	0.9471055***	0.8229089***	0.8446033***
eta	0.0030507		0.0026083	
lnsigma2	−2.547376***	−2.540672***	−2.577198***	−2.572713***
ilgtgamma	2.79794***	2.801286***	2.7772251***	2.774867***

Note *** Significant at 1%, **Significant at 5%, * Significant at 10%.
Source: Own Elaboration.

the logarithms of the full-time employees (*ln empl*), representing capital and labor, respectively. The environmental variables we include are: the proportion of metered clients (*mete*), the proportion of losses in the net ("unaccounted for water") (*loss*), and the logarithm of the population density by water main kilometers (*ln dens*).

The signs of the input coefficients (marginal productivities) are positive, as was expected, and both are significant and robust in all the specifications. The logarithm of population density coefficient is positive, significant and robust in all the specifications. The proportion of metered clients' coefficient is negative, significant and robust in all the specifications. The positive sign of the density coefficient is expectable, as is the negative one for metering. The former variable saves inputs, while the second consumes more resources when compared with a non-metered tariff system.

The country coefficients have different signs; their absolute values are relatively robust but they are significant in only some cases (Costa Rica, Ecuador, Honduras and Panama). The Multisectoral Regulator dummy (to distinguish from specialized or "sectoral" ones) has a negative and robust coefficient but it is not significant in any case.

In the translogarithmic specification, the coefficients of the quadratic effects and that of the interactions between the inputs are not significant in any case.

Two criteria can decide which specification is indicated. One considers the individual significance tests of the β_{nm} interaction coefficients in the translog formula while the other considers the likelihood ratio since the first criteria could be misleading.

In this case, the likelihood ratio test supports the Cobb-Douglas specification over the translogarithmic (see Table 4). At the same time, the quadratic and interaction coefficient in the second one is not significant. We conclude that the Cobb-Douglas functional form is a better representation of the phenomena under study.

When testing whether the TVD or the TI Cobb-Douglas specification is preferable, the nonsignificant eta value in the TVD model (Table 3) plus the likelihood ratio value (Table 4) support the TI version. It makes sense since we have data for only five periods and the technological change in the water sector is not very dynamic.

Also, the efficiency measures from the estimates have an acceptable degree of variability among providers. We present the descriptive statistics of the efficiency measures obtained from the previous models in Table 5.

The difference between minimum and average values is striking and, more importantly, the standard deviation shows variability ranges which are acceptable in the normal practice of these measures.

Table 4
Test on different econometric models.

	Log-likelihood	$\mu = 0$	$\gamma = 0$	$\eta = 0$	Selected model
Cobb-Douglas TVD	227.11	Rejection at 1%	Rejection at 1%	Non Rejection	
Cobb-Douglas TI	226.64	Rejection at 1%	Rejection at 1%		X
Translogarithmic TVD	229.87	Rejection at 1%	Rejection at 1%	Non Rejection	
Translogarithmic TI	229.59	Rejection at 1%	Rejection at 1%		

Source: Own Elaboration.

Table 5
Descriptive statistics of the efficiency measures in the production frontier models.

Model	Observations	Average	Standard Deviation	Minimum	Maximum
Cobb-Douglas TVD	339	0.417	0.129	0.225	0.9345
Cobb-Douglas TI	339	0.439	0.148	0.218	0.927
Translogarithmic TVD	339	0.455	0.135	0.253	0.940
Translogarithmic TI	339	0.480	0.150	0.248	0.936

Source: Own Elaboration.

To test the hypothesis that the firms are technically efficient, we contrast the estimate of γ which is rejected in all cases and conclude that the effects are random.

Lastly, the exercise yields conclusive evidence: if we assume a Cobb-Douglas function, the inefficiencies do not vary across time and the choice is a TI-type model.

To address multicolineality between variables, we explore the correlation matrix between regressors. We find correlation between the inputs capital and labor, which is theoretically admissible since they are substitutes at certain levels. We also run the same regressions of the accepted model with the randomly reduced database. In 80 different regressions, we find small changes in the coefficient values while the signs and significance of the estimates remain.

In synthesis, the preferred model has a Cobb-Douglas functional form (rather than a Translogarithmic), which does not enable inefficiencies to vary across time (TI). For outputs we use the logarithm of dispatched water, and the logarithm of employment and of mains length for inputs. The logarithm of the population density, the proportion of metered clients and the proportion of water losses (over dispatched water) are included in the model as environmental variables. We add country dummies to account for specifics of the 14 different countries included in the sample and add a dummy for multisectoral regulator since the task is often carried out by an agency which also oversees electricity, transport, solid waste, and so on.

6. Conclusions

Our aim was to analyze the efficiency of the water sector in Latin American countries. We try to find factors affecting efficiency rather than identifying which country (or provider) is more or less efficient. We also consider which model would be more fitting for the water sector in this region. Our motivation is to develop instruments to make benchmarking operative for regulatory actions that can reduce information asymmetry and increase efficiency in Latin American countries.

Comparisons could be used to boost changes in the internal behavior of the providers or to set external stimuli from the regulators. They could be used to save inputs, to improve resource allocation and to achieve desirable social goals (such as increased coverage or higher quality levels). Comparative studies at an aggregate level could indicate which services are weak in terms of efficiency and leave it up to the managers to decide where and when the improvements have to be implemented. They are also useful to regulators, who could decide where and when to exercise more pressure or request more information.

The paper estimates econometric efficiency frontiers with data from ADERASA's regional survey. It develops a model based on the core variables that explain the phenomena and explores "environmental" variables as a way to achieve fair comparisons. The study does not "name and shame" services but provides elements to foster the development of indicative goals at the regional level.

Our overall criterion is to estimate production frontiers that depend only on physical data. The more suitable production frontier has a Cobb-Douglas functional form, a TI model, indicating that the inefficiencies do not vary across time and that the firms can control them better (random effects).

The regulatory use of the results can follow far-reaching or less ambitious approaches. The idea of using cross-country studies to set tariffs is currently too complex for the Latin American region. In the first case – "yardstick competition" – the estimates are instruments to discuss tariffs and performance goals; a second and more limited approach, especially in the international arena, could yield a consensus on some standards and practices, which can be based on the experiences of better-situated peers. Finally, "sunshine competition" presents best practices and reveals good and bad cases ("name and shame").

We present a protocol with an implicitly established "to do" list. A first step would be to improve the quality of the information and to disclose and discuss the results. We hold that this can be followed up by establishing minimum standards at the regional level. Once the regulators have reached a consensus over a reasonable period of time, comparative information could begin to be made public. A second step could be "sunshine competition". With a correct identification of specificities in the quality of service and different regulatory environments, the comparisons would be fairer and more acceptable to the parties. Also, disclosure could initially include the better performing units (for example, above or below average) without identifying the worst performers. Our findings show that a discussion of the nature of the efficiency differences is viable.

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