RESEARCH ARTICLE

inventi Spreading Knowledge

Returns to Scale in Water and Sanitation: Estimates for Latin America

Gustavo Ferro[1]*, Emilio J. Lentini[2], Augusto C. Mercadier[1], Carlos A. Romero[1]

Abstracts: Most countries around the world are strongly debating ways to yield more equitable access and a more efficient provision. One issue linked to efficiency is the achievement of scale economies in the industry and the optimal dimension of water and sanitation providers.Changes in the industrial structure of the sector, through mergers in highly atomized services, the breakup of very concentrated services, or the property discussion (private versus public) are major issues. These decisions have often become politicized because of the social complexity of the sector. Empirical findings of the different models reveal the existence of increasing returns to scale in Latin American water provision based on an ADERASA database (a 2005 cross section of 90 providers in 14 countries). The study of returns to scale incorporates a technical argument into the discussion because–as our study suggests–the prescription could be to agglomerate small providers.

Key Words: water, sanitation, scale, Latin America

INTRODUCTION

Certain features of the water and sanitation sector[i] make it unique. Firstly, the industry is highly capital intensive and most of its capital is sunk. Technical change in the sector, largely as a consequence of the former, has been very slow to develop. Secondly, that water and sanitation are vital to life implies complex social and political interrelations.

Since water and sanitation are local monopolies, they tend to be controlled by municipalities whose scale of operations tends to be smaller than the optimal scale for provision, implying inefficiencies.

Most countries around the world are strongly debating ways to yield more equitable access and a more efficient provision. One issue linked to efficiency is the achievement of scale economies in the industry and the optimal dimension of water and sanitation providers.

Changes in the industrial structure of the sector, through mergers in highly atomized services, the breakup of very concentrated services, or the property discussion (private versus public) are major issues. These decisions have often become politicized because of the social complexity of the sector.

In this study, we aim to estimate the presence of returns to scale based on a database of water and sanitation providers in Latin America. Public policy consequences are direct: if those returns to scale do exist, and the sector is not taking advantage of them, the agglomeration of small providers can eventually save resources which could help solve the coverage shortages and the insufficient access of the poor in the region.

The paper is organized as follows: Section 2 presents theoretical issues related with empirical estimates of returns to scale and scale economies in the water and sanitation sector. Section 3 briefly synthesizes the findings of the empirical literature on the issue. Section 4 describes the database used. Section 5 presents the methodology and estimates and Section 6 concludes.

THEORETICAL ISSUES

From a theoretical point of view, and given a production function $y = f(x1, x2)$, increasing (decreasing) returns to scale exist when increasing input usage x_i as a proportion of "t", output y grows in a greater (lower) proportion than the former increase in inputs. This implies $f(tx_1, tx_2) > tf(x_1, x_2)$ for increasing returns to scale (and the contrary is true for decreasing returns). If $f(tx_1, tx_2) = tf(x_1, x_2)$ then, there are constant returns to scale.

That definition has a correlate in the cost function: an increase in the returns to scale in the production function can lead to economies of scale; a decrease in the returns to scale implies diseconomies of scale. Therefore, to estimate economies of scale (returns to scale) we must first define product (y) and then define a cost (C) or production (F) function.

The use of a production or a cost function implies different economic assumptions about the firm: one, the firm seeks to maximize output by choosing the optimal input combination for a given budget constraint; and two, it seeks to minimize production costs, opting for the necessary input to achieve a given output level. Under certain regularity conditions, it is possible to prove that the cost function is the dual of the production function. Thus, production technology can be characterized as using both production and cost functions. Despite the duality of cost and production functions at the theoretical level, the empirical specification has different implications.

In a production function regression we assume an endogenous output level since the input quantities are exogenous. In contrast, costs and input quantities in a cost function are endogenous while output is exogenous.

In the water and sanitation context, two reasons favor the usage of a cost function. Firms are obliged to provide all customers with a minimum quality standard. They also tend to be price takers in the input markets.

Nevertheless, the cost estimates have difficulties of their own: nominal values are not easy to compare in inflationary environments, and cross-country studies show that the purchasing power parity is also difficult to assess. These problems are particularly relevant to this study as it tests the accuracy of the monetary magnitude in the database.[ii] For all of these reasons, we take a production function approach.

This paper is a contribution to the economic literature with respect to scale economies in the water and sanitation sector. Firstly, only few studies estimate production functions (and returns to scale); most estimate short- or long-run cost functions. Secondly, there are not many cross-country studies on the subject and, to our knowledge, it is the first to focus on the Latin American region.

After defining the inputs of the production function, other variables influence the returns to scale, which have nothing to do with the efficiency level of the firm but rather with the operational environment. These variables are called "environmental", hedonic or controls. They allow us to take into account the different operative and technical conditions of the firms: the type of customer, the territorial density of the service, the quality of the product and so on.

The production process is represented by the function $f(y, x; Z) = 0$, where y is the output vector, x the input vector, and Z the environmental variables vector which helps to characterize the underlying technology.

The following is a simplified representation of the Cobb-Douglas function and its logarithmic form:

$$y = \beta_0 \prod_{n=1}^{N} x_n^{\beta_n} \tag{1}$$

$$\ln y = \ln \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_n \tag{2}$$

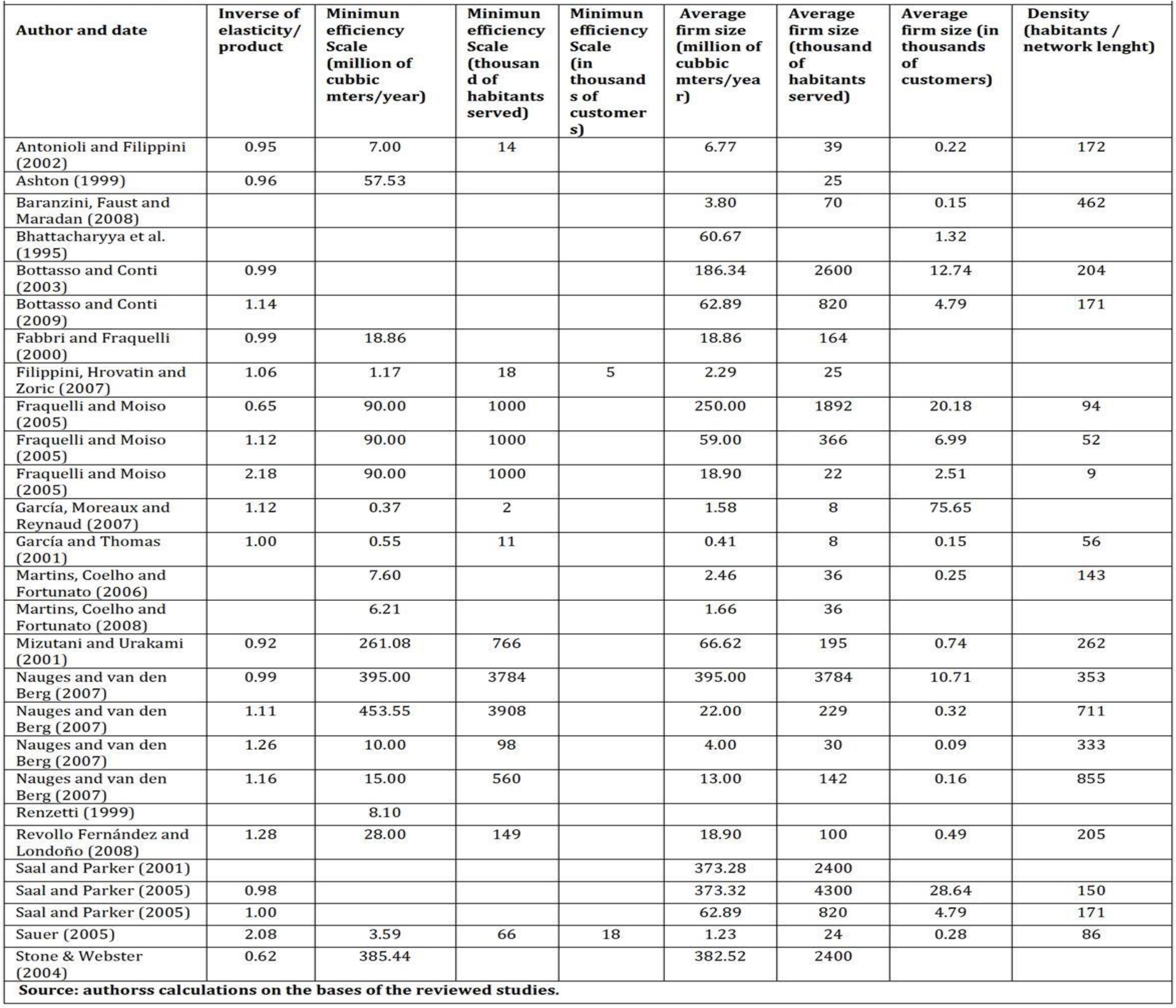
The Cobb-Douglas formula is quite common in the empirical literature because of its simplicity and easy interpretation. But, it imposes unnecessary constraints on production technology, in particular, with regard to scale economies, implying that they are the same at any level of production.

---

[1]Instituto de Economía UADE and CONICET, Lima 717 (1073) Buenos Aires , Argentina
Email: gferro@uade.edu.ar
*For correspondence

[2]Centro de Estudios Transdisciplinarios del Agua – (FCV) UBA and GDR « Res-Eau-Ville, Argentina
Email : ejlentini@yahoo.com.ar

Table 1: Summary Of Quantitative Results Of Reviewed Studies



Author and date	Inverse of elasticity/ product	Minimun efficiency Scale (million of cubbic mters/year)	Minimun efficiency Scale (thousand of habitants served)	Minimun efficiency Scale (in thousands of customers)	Average firm size (million of cubbic mters/year)	Average firm size (thousand of habitants served)	Average firm size (in thousands of customers)	Density (habitants / network lenght)
Antonioli and Filippini (2002)	0.95	7.00	14		6.77	39	0.22	172
Ashton (1999)	0.96	57.53				25		
Baranzini, Faust and Maradan (2008)					3.80	70	0.15	462
Bhattacharyya et al. (1995)					60.67		1.32	
Bottasso and Conti (2003)	0.99				186.34	2600	12.74	204
Bottasso and Conti (2009)	1.14				62.89	820	4.79	171
Fabbri and Fraquelli (2000)	0.99	18.86			18.86	164		
Filippini, Hrovatin and Zoric (2007)	1.06	1.17	18	5	2.29	25		
Fraquelli and Moiso (2005)	0.65	90.00	1000		250.00	1892	20.18	94
Fraquelli and Moiso (2005)	1.12	90.00	1000		59.00	366	6.99	52
Fraquelli and Moiso (2005)	2.18	90.00	1000		18.90	22	2.51	9
García, Moreaux and Reynaud (2007)	1.12	0.37	2		1.58	8	75.65	
García and Thomas (2001)	1.00	0.55	11		0.41	8	0.15	56
Martins, Coelho and Fortunato (2006)		7.60			2.46	36	0.25	143
Martins, Coelho and Fortunato (2008)		6.21			1.66	36		
Mizutani and Urakami (2001)	0.92	261.08	766		66.62	195	0.74	262
Nauges and van den Berg (2007)	0.99	395.00	3784		395.00	3784	10.71	353
Nauges and van den Berg (2007)	1.11	453.55	3908		22.00	229	0.32	711
Nauges and van den Berg (2007)	1.26	10.00	98		4.00	30	0.09	333
Nauges and van den Berg (2007)	1.16	15.00	560		13.00	142	0.16	855
Renzetti (1999)		8.10						
Revollo Fernández and Londoño (2008)	1.28	28.00	149		18.90	100	0.49	205
Saal and Parker (2001)					373.28	2400		
Saal and Parker (2005)	0.98				373.32	4300	28.64	150
Saal and Parker (2005)	1.00				62.89	820	4.79	171
Sauer (2005)	2.08	3.59	66	18	1.23	24	0.28	86
Stone & Webster (2004)	0.62	385.44			382.52	2400		

Source: authorss calculations on the bases of the reviewed studies.

Christensen, Jorgenson, and Lau (1973) use the translogarithmic (or translog) to capture the scale economies that Cobb-Douglas could not:

$$\ln y = \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_n + \frac{1}{2} \sum_{n=1}^{N} . \sum_{m=1}^{M} \beta_{nm} \ln x_n . \ln x_m \qquad (3)$$

The translog function has the advantage of being more flexible than Cobb-Douglas. It does not impose *a priori* constraints on input substitution feasibility and allows scale economies to vary together with the output level.

Hence, the more recent empirical studies commonly use a translog function that is more flexible and nests the Cobb-Douglas as a particular form. The log-lineal Cobb-Douglas formula is the particular case of the translog when all the interaction terms βnm are equal to zero.

On the other hand, the translog formula could be understood as a second order Taylor expansion in the logarithm of a cost/production function with some constraints on the parameters to hold the desired properties (symmetry and homogeneity). The disadvantage of the translog function is that it is only a local approximation and its results are only locally reliable around the approximation point. Since some properties are not imposed, they have to be verified *ex post* based on the estimated coefficients.

The translog function has been of ample use in scale economy studies because of its properties. In the multiproduct context, it has another disadvantage when the output level of one or more products is zero. In that case, the formula has limitations computing scope economies. This is relevant in the water and sanitation sector since providers usually produce both products; in turn, the water service could be considered scale and scope economies at each stage of the productive chain (abstraction, purification, transportation, distribution and commercial).[iii]

To measure scale economies, calling E the cost elasticity with respect to scale (as cost change in percentages before a given change in scale or the size of a firm), if E = 1 there are

Table 2a: Overview of reviewed literature (first part)

Author and date	Antonioli and Filippini (2002)	Ashton (1999)	Baranzini, Faust and Maradan (2008)	Bhattacharyya et al, (1994)	Bhattacharyya et al, (1995)	Bottasso and Conti (2003)	Bottasso and Conti (2009)	De Vitte and Dijkgraaf (2007)	Fabbri and Fraquelli (2000)	Filippini, Hrovatin, Zoric (2007)	Fraquelli and Moiso (2005)	García, Moreaux and Reynaud (2007)	García and Thomas (2001)	Hayes (1987)
Country/region	Italy	England & Wales	Switzerland	USA	USA	England & Wales	England & Wales	Netherland	Italy	Slovenia	Italy	USA	France	USA
Estimation method	RE	GLS, SUR					Several	COLS	SUR	Several	ML	GMM	GMM	OLS
Num. Of firms	32	20	113	257	221	28 to 21	18 to 12	20 to 10	173	52	18	233	55	475
Period/date	1991-1995	1991-1996	2002-2005	1992	1992	1995-2001	1995-2005	1992-2006	1991	1997-2003	30 years	1997-2000	1995-1997	1960,1970,1976
Technology: Cobb-Douglas												Yes	Yes	Yes
Technology: Translog	Yes		Yes			Yes		Yes		Yes				
Technology: Cuadratic		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Technology Cubic														Yes
Other Technology														
Variable Cost Function								Yes						
Total Cost Function	Yes	Yes	Yes	Yes	Yes	Yes	Yes					Yes	Yes	
Output: Volume of water produced			Yes					Yes	Yes	Yes	Yes			Yes
Output: Customer or water connections	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	S	Yes	Yes	Yes	Yes	Yes
Output: Wholesale water							Yes							
Output: Water losses												Yes		Yes
Output: Service Area													Yes	
Output: Volume of water delivered							Yes							
Output: Customer or sewage connections														
Input: Labor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Input: Energy		Yes	Yes	Yes	Yes						Yes	Yes	Yes	
Input: Capital				Yes	Yes			Yes	Yes	Yes	Yes			
Input: Others		Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	
Hedonic/ control/environmental	Serveral	Serveral	Serveral	Ownership	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral	NA
Scale economies (output)							Yes			Yes	Yes	Yes		
Constant scale	Yes	Yes				Yes			Yes	Yes	Yes		Yes	

neither economies nor diseconomies of scale. If E > 1, the firm will exhibit diseconomies of scale. If E < 1 it will indicate scale economies. The reported results of the studies were standardized using the reciprocal of the cost elasticity with respect to the output. The measure (1/E) > 1 denotes increasing returns to scale (scale economies in the cost function), (1/E) < 1 reveals decreasing returns to scale (diseconomies of scale in the cost function), and (1/E) = 1 indicates constant return to scale (the absence of scale economies or diseconomies).

A REVIEW OF THE EMPIRICAL LITERATURE

Until the 1990s the tendency of the empirical studies in water and sanitation scale economies focused on the small size of some providers and the efficiency discussion between public and private providers. Many studies tended to examine the cost savings of scale economies derived from the mergers of atomized providers in the US and to estimate the comparative performance of private and public operators.

From the 1990s the research agenda shifted to England and Wales based on the privatization of the sector in 1989. Private provision triggered an interest in the performance and optimal size of the enterprises. During the 1990s, a wave of mergers and acquisitions in England and Wales consolidated the industry. Researchers tried to assess whether mergers actually improved welfare for society or simply implied higher profits for the firms (and more monopoly power).

Later, the literature showed an interest in Italy, where legislation in 1995 aimed to amalgamate a highly atomized sector in Optimal Territorial Units (ATOs in Italian). New, richer and more complex techniques were implemented at the time. The problem of very small and inefficient providers was common in other Continental European countries, such as France, Germany, Portugal, Switzerland, Spain, the Netherlands, Slovenia and Romania. Similar discussions were also documented in South Korea, Japan, Canada and Colombia.

Cross-country studies are scarce but some recent efforts, mainly from international organizations, have been able to build large databases covering diverse countries.

A significant set of studies from many countries yields economies of scale with populations ranging between 100 thousand and 1 million or more, with population densities of 250 inhabitants per square kilometers, or with volumes of water provision totaling almost 70 million cubic meters per year. Larger populations, densities or volumes tend to give rise to diseconomies of scale and lower values produce cost savings for an agglomeration of small providers.

Table 1 presents a brief review of the literature. Most of the studies report economies of scale, constant scale economies, or moderate diseconomies, except in some cases involving major providers.

Table 2b: Overview of reviewed literature (second part)

Author and date	Hunt and Lynk (1995)	Kim and Clark (1988)	Kim and Lee (1998)	Martins, Coelho and Fortunato (2006)	Martins, Coelho and Fortunato (2008)	Mizutani and Urakami (2001)	Nauges and van den Berg (2007)	Nauges and van den Berg (2008)	Renzetti (1999)	Revollo Fernández and Londoño (2008)	Saal and Parker (2001)	Saal and Parker (2005)	Stone and Webster (2004)	Torres and Paul (2006)
Country/region	England & Wales	USA	South Korea	Portugal	Portugal	Japan	Several	Several	Canada	Colombia	England & Wales	England & Wales	England & Wales	USA
Estimation method	OLS	ML	SUR	OLS	OLS	SUR	SUR			GMM				ML
Num. Of firms	NA	60	42	218	282	112	360	295	77	126	10	20	38	255
Period/date	Yes	Yes		Yes	Yes					Yes	Yes		Yes	Yes
Technology: Cobb-Douglas						Yes				Yes				
Technology: Translog	Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Technology: Cuadratic				Yes						Yes			Yes	
Technology Cubic					Yes									
Other Technology														Yes
Variable Cost Function							Yes	Yes		Yes			Yes	Yes
Total Cost Function	Yes	Yes	Yes	Yes	Yes	Yes			Yes		Yes	Yes	Yes	
Output: Volume of water produced	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Output: Customer or water connections													Yes	
Output: Wholesale water														Yes
Output: Water losses				Yes										
Output: Service Area														
Output: Volume of water delivered	Yes				Yes			Yes			Yes	Yes	Yes	
Output: Customer or sewage connections	Yes													
Input: Labor	Yes	Yes				Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
Input: Energy		Yes				Yes	Yes	Yes	Yes	Yes			Yes	Yes
Input: Capital	Yes					Yes	Yes	Yes		Yes	Yes		Yes	Yes
Input: Others	Serveral	Serveral	Density	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral	Serveral
Hedonic/ control/environmental		Yes					Yes	Yes	Yes	Yes	Yes			
Scale economies (output)		Yes				Yes	Yes		Yes	Yes				
Constant scale economies (1/E) +/- 5%		Yes											Yes	Yes

Also, we can see a significant variability in the optimal size of the providers, measured in terms of volume, inhabitants, or customers. These differences may have to do with geographical, historical, institutional, legal and regulatory factors.

Table 2 presents the different methodologies used in the computation of the results of the preceding table. Some authors work with panel data while others perform estimates with cross sections. In most of the cases the translog specification is preferred to the Cobb-Douglas or other specification, such as the cuadratic. The estimation strategy, generally consists on estimating a system of equations through the Seemingly Unrelated Regression (SUR) procedure. In general, the system comprise: the cost function, the share equations of all but one input, and a set of constraints that guarantee symmetry and homogeneity.

In most of the studies, output is the volume of potable water (produced or delivered) to residential, non-residential or both customers. The difference between produced and delivered water is network losses ("unaccounted for water"). Other studies use serviced inhabitants or customers (connections) as output.

The estimates are comprised of four main inputs: labor, capital, energy and raw materials. In some cases, other inputs are taken into consideration, like hired services or block water purchases.

Since the studies in their great majority are estimates of cost functions, the underlying assumption is that firms minimize costs given the input prices. To determine the average wage, wages are divided per number of workers based on balance sheet data.

To determine energy price, in some cases the average price of the kWh is estimated by dividing energy expenses by the quantity of energy consumed, and in others an index of energy cost from official statistics was taken.

The unit price of "raw materials", as long as it groups very heterogeneous concepts, has been calculated by choosing a representative official price index to apply.

The capital price is normally estimated as a residual category: the non-labor costs are divided into some physical unit approximating the capital stock of the firms, typically, network length.

With respect to "environmental" variables, most of the cases used the network length, the number or type of customers, and/or density variables.

The network length is sometimes added as a proxy of the capital stock; other times it is incorporated to reflect different intensities in energy input.

Density variables seek to capture differences in costs because of the concentration or dispersion of the demand.

The customer types influence the costs: those firms with a larger number of non-residential customer normally have lower costs than firms which supply a majority of residential customers because of a more concentrated demand, lower commercial expenses and so on.

Likewise, some authors have incorporated variables that distinguish between different sources of water since surface water demands more chemicals, unlike underground water that has a higher consumption of electricity.

Finally, some variables reflect differences in the operative environment, such as pipe breaks, water losses, the types of property of the provider (public or private) and quality standards.

THE DATABASE

To make the estimates, we use a database from ADERASA, comprising providers from 14 Latin American countries with 90 observations for the year 2005.[iv] From that database we select representative variables for products, inputs and controls.

The selected variables to represent output are the quantity of water customers (ln_clia), water volume produced (ln_volu) and coverage measured as the number of inhabitants (ln_cobe).

The productive factors are capital and labor. The water network length measured in kilometers represents the former (ln_reda), and the latter measures represent the full-time equivalent workers (ln_labo).

As the output and input variables are expressed in logarithms, the estimated

Table 3: Descriptive Statistics

Variable	N	Mean	Largest	Minimun	Std Dev	Variance	Skewness	Kurtosis
ln clia	90	11.15	14.83	7.02	1.55	2.40	-0.1283	3.12
ln volu	90	11.31	15.28	6.84	1.53	2.35	-0.0648	3.43
ln cobe	90	12.54	15.87	8.65	1.51	2.30	-0.0794	2.96
ln reda	90	6.59	9.82	3.04	1.36	1.85	0.1939	2.69
ln labo	90	5.48	8.64	1.09	1.41	2.00	-0.3797	3.89
ln dens	90	5.94	7.00	3.89	0.47	0.22	-0.8508	5.55
medi	90	0.74	1.00	0.00	0.31	0.09	-1.1322	2.83
Sane	90	0.79	1.23	0.00	0.28	0.07	-1.6142	4.69
Resi	76	0.74	1.00	0.28	0.12	0.01	-1.0128	5.34
anco	90	0.40	0.85	0.08	0.12	0.01	0.3104	4.23

Source: authors' calculations

Table 4: Output Correlation Matrix

	ln clia	ln volu	ln cobe
ln clia	1.0000		
ln volu	0.9615	1.0000	
ln cobe	0.9864	0.9636	1.0000

Source: authors' calculations

coefficients of the estimates can be interpreted as elasticities.

We have selected some environmental variables to capture the difference in the operational realm of the firms, trying to determine their impact on the scale and the optimal size of operations:

- Customer density by kilometer of network (ln_dens), trying to determine differences in the productivity factor arising from concentrated or dispersed demand. That variable is measured in logarithms to reflect percentage changes.
- Percentage of metered customers (medi).
- Percentage of the population with sewerage services (sane).

The weight of residential sales out of total sales (resi) accounts for the demand structure.

The percentage of water losses or "unaccounted for water" (anco).

Table 3 presents descriptive statistics of the selected variables.

To estimate the production function, we first have to identify the products a water provider offers. The outputs could be estimated according to the volume of water produced or distributed (measured in cubic meters), customer access to a water network (as the proportion of covered inhabitants), the amount of serviced people or customers, or considering the firms as multi- product firms, where the three products or a combination is provided. The same is true for sewerage, although sewage water has its origin in potable water entering the property; in most cases, properties with sewerage also have water, while many water connections do not have sewerage.

Table 4 presents the simple correlations between the three output variables. They are highly and positively correlated. Thus, it is not possible to take more than one product at a time, and we considered only one product in each estimate in the production function estimate.

Considering the above, the following step is to analyze the sample correlation between each of the output, input, and environmental variables.

The exercise has a twofold purpose. On the one hand, it determines the more predictable variables in relation to the selected output. On the other, it tries to address possible multicolineality problems between the explanatory variables. A high correlation between the variables could undermine the significance of the estimates, making them inconclusive.

Tables 5 to 7 present the correlations between customers, volumes and population coverage and the explanatory variables. In the three cases there is a high correlation between output and inputs, and between both inputs. This result may indicate that both network and workers well-explain production. On the correlations between productive factors, control variables and between the control variables themselves, we find no serious correlation problems.

ESTIMATION METHODOLOGY AND EMPIRICAL RESULTS

To estimate the production function, we use a Cobb-Douglas specification:

$$\ln y = \ln \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_n + \sum_{m=1}^{M} \beta_m \ln z_m \qquad (4)$$

Where:

- (y) is the output, alternatively represented by customers, volume and coverage
- (x_n) are the inputs, capital and labor
- (z_m) are the environmental variables representing the five control variables: demand structure, density, metering, sanitation coverage, and water losses.

We also estimate other specifications like the translog described in equation (3), as well as in the simpler formulations (models A1, B1, and C1). All the β_{nm} were nonsignificant, so we can infer that the Cobb-Douglas is an acceptable specification.

Next, we present 18 production functions, six for each product. The first estimate in each of the six sets only includes the inputs as explanatory variables and we then add the five environmental variables one by one.

Table 8 presents the results using customers as output. In the different specifications, the input coefficients are significant at 1 percent. Since returns to scale imply that output increases more than proportionally to input growth, and that the coefficients of the variables in logarithms can be understood as percentage changes, the returns to scale are derived from the sum of the coefficients of both inputs. All of the estimates show increasing returns to scale from 1.0540 to 1.1344.

Likewise, with the exception of customer density, the remaining environmental variables are nonsignificantly different from zero.

Table 9 shows that when we consider ln_volu as output, the input coefficient becomes significant with the exception of ln_labo in the specification (B2).

Returns to scale oscillate between 0.9914 and 1.0854, and three out of five environmental variables are nonsignificant. As the customer density increases, the data indicate that proportionate increases in capital and labor lead to higher returns in more densely populated regions. Model B5 shows that when residential customers grow, water production volume reduces, *ceteris paribus*.

This is because, on average, the non-residential customers' consumption is higher than that of residential customers. Unaccounted for water in B6 implies that the greater the water losses, the greater the water production.

Table 10 presents the specification for ln_cobe as a dependent variable. With the exception of ln_labo in Model C2, the remaining coefficients are significant at 1 percent. The environmental variables are nonsignificant with the exception of customer density. Returns to scale vary between 1.0004 and 1.1068.

CONCLUDING REMARKS

Empirical findings of the different models reveal the existence of increasing returns to scale in Latin American water provision based on an ADERASA database (a 2005 cross section of 90 providers in 14 countries). The Cobb-Douglas specification we use has the disadvantage that the elasticities are constant throughout the range of analysis.

The adjusted R2 yields very high values for cross section analysis, which suggests that the

Table 5: Ln Clia (N = 90) Input And Hedonic Variable Correlation Matrix

	ln clia	ln reda	ln labo	ln dens	medi	sane	resi	anco
ln clia	1.0000							
ln reda	0.9626	1.0000						
ln labo	0.8859	0.8301	1.0000					
ln dens	0.3433	0.1220	0.4185	1.0000				
Medi	0.0741	0.0329	-0.0108	0.2081	1.0000			
Sane	0.3500	0.3277	0.2942	0.1221	0.3141	1.0000		
Resi	-0.2037	-0.1787	-0.1794	-0.1359	-0.0078	0.1084	1.0000	
Anco	-0.0847	-0.1167	0.0649	0.1078	-0.1829	-0.1668	0.0141	1.0000

Source: authors' calculations

Table 6: Input and Hedonic variable correlation matrix for ln volu (N = 90)

	ln volu	ln reda	ln labo	ln dens	medi	sane	resi	anco
ln volu	1.0000							
ln reda	0.9390	1.0000						
ln labo	0.8331	0.8301	1.0000					
ln dens	0.3256	0.1220	0.4185	1.0000				
Medi	0.0143	0.0329	-0.0108	0.2081	1.0000			
Sane	0.2821	0.3277	0.2942	0.1221	0.3141	1.0000		
Resi	-0.2515	-0.1787	-0.1794	-0.1359	-0.0078	0.1084	1.0000	
Anco	-0.0093	-0.1167	0.0649	0.1078	-0.1829	-0.1668	0.0141	1.0000

Source: authors' calculations

Table 7: Input and Hedonic variable correlation matrix for ln cobe (N = 76)

	ln cobe	ln reda	ln labo	ln dens	medi	sane	resi	anco
ln cobe	1.0000							
ln reda	0.9610	1.0000						
ln labo	0.8861	0.8301	1.0000					
ln dens	0.3917	0.1220	0.4185	1.0000				
Medi	0.0887	0.0329	-0.0108	0.2081	1.0000			
Sane	0.3380	0.3277	0.2942	0.3702	0.5144	1.0000		
Resi	-0.2039	-0.1787	-0.1794	-0.1359	-0.0078	0.0934	1.0000	
Anco	-0.0781	-0.1167	0.0649	0.1078	-0.1829	-0.2325	0.0141	1.0000

Source: authors' calculations

`models are well specified. In 16 of the 18 specifications the input coefficients are significant and have the expected signs.

The environmental variables were not significant in the great majority of the cases.

The results indicate the existence of returns to scale in the sample with values that are in line with scale economies estimated in many other country studies.

A more extended database over a longer period would allow us to test the robustness of the results using a panel data study. That would be a natural extension of this analysis. Also, the panel allows for the grouping of small, medium and large providers. The environmental variables should be refined to be able to draw more detailed findings.

The results, nevertheless, have important implications for public policy. The sector has been the object of centralization or decentralization policies, depending on the decade we examined, which in general were not due to the optimal scale of production. The study of returns to scale incorporates a technical argument into the discussion because–as our study suggests–the prescription could be to agglomerate small providers. A logical consequence, then, is to try to find an operative concept of optimal scale provision. The study of the return to scale (scale economies) also helps to determine how far it is necessary to agglomerate since both the theory and the evidence indicate that at some point firms become too big, giving rise to decreasing returns (scale diseconomies).

REFERENCES AND NOTES

1. Antonioli, B. and M. Filippini (2001). "The use of a variable cost function in the regulation of the Italian water industrand," Utilities Policy, Elsevier, vol. 10(3-4), pages 181-187.
2. Ashton, J. (1999), Economies of scale, economies of capital utilization and capital utilization in the English and Welsh water industry, Bournemouth University, School of Finance and Law Working Paper Series, 17
3. Baranzini, Andrea, Anne-Kathrin Faust and David Maradan (2008). Water supply: costs and performance of water utilities. Evidence from Switzerland. 13th International Water Resources Association. World Water Congress. Montpellier, 1-4 September.
4. Bhattacharya, A., E. Parker and K. Raffiee (1994). "An examination of the effect of ownership on the relative efficiency of public and private water utilities". Land Economics 70(2), pp. 197-209.
5. Bhattacharyya, A., T. R. Harris, R. Narayanan and K. Raffiee (1995). Specification and estimation of the effect of ownership on the economic efficiency of the water utilities. Regional Science and Urban Economics 25, 759-784.
6. Berg, Sanford and Claudia Vargas (2008). Bolivian utility regulation: lessons for a water sector agency. Paper # 08-11. Public Utility Research Center, University of Florida.
7. Bottasso, A. and M. Conti (2003). "Cost Inefficiency in the English and Welsh Water Industry : An Heteroskedastic Stochastic Cost Frontier Approach". Noviembre.
8. Bottasso, A. and M. Conti (2009). "Scale economies, technology and technical change in the water industry: Evidence from the English water only sector". Regional Science and Urban Economics 39 (138–147).
9. Chamber, Robert (1988). Applied production análisis. Cambridge: Cambridge University Press.
10. Christensen L. R. and W. H. Greene. Economies of scale in U.S. electric power generation. Journal of Political Economy 84, 655–676.
11. Christensen, Laurits, Dale Jorgenson and Lawrence Lau (1973). "Transcendental Logarithmic Production Frontiers". The Review of Economics and Statistics, MIT Press, vol. 55(1), pages 28-45, February.
12. De Witte, Kristof and Ebert Dijkgraaf (2007). Mean and bold? On separating merger economies from structural efficiency gains in the drinking water sector. Tinbergen Institute Discussion Paper 2007-092/3
13. De Witte, Kristof and Rui Marques (2007). Designing Incentives in Local Public Utilities, an International Comparison of the Drinking Water Sector. Discussion Papers 07-32. University of Leuven.
14. Estache, Antonio and Martín Rossi (2005). Relevance of reforms, institutions and basic economics for the economic efficiency of African water utilities. Policy Research Working Paper . The World Bank, June.
15. Farsi, Mehdi, Aurelio Fetz and Massimo Filippini (2007). Benchmarking and Regulation in the Electricity Distribution Sector. CEPE Working Paper N° 54. Swiss Federal Institutes of Technology. January.
16. Farsi, Mehdi, Aurelio Fetz and Massimo Filippini (2008). Economies of Scale and Scope in Multi-Utilities. The Energy Journal. October. The International Association for Energy Economics.
17. Filippini, Massimo, Nevenka Hrovatin and Jelena Zoric (2008). Cost Efficiency and Economies of Scale of Slovenian Water Distribution Utilities: An Application of Panel Data Sthocastic Frontier Methods. Journal of Productivity Analysis. Vol 29, Issue 2 (April), pp. 169-182.
18. Fraquelli, Giovanni, Massimiliano Piacenza and Davide Vannoni (2002). Scope and Scale Economies in Multi-Utilities: Evidence From Gas, Water and Electricity Combinations. XIV Conferenza Società Italiana di Economia Pubblica. Dipartamento di Economia Pubblica e Territoriale. Università di Pavia.
19. Fraquelli, Giovanni, Massimiliano Piacenza and Davide Vannoni (2004). Cost savings from generation and distribution with an application to Italina electric utilities. Mimeo.
20. Fraquelli, Giovanni and Valentina Moiso (2005). Cost Efficiency and Economies of Scale in the

Table 8: OLS Estimates for Ln Clia = f(ln reda, ln labo, hedonic variables)

Model		A 1	A 2	A 3	A 4	A 5	A 6
ln clia	constant	4.0835	-0.1245	3.9602	4.0655	4.3787	4.1702
Input	Ln reda	0.7583*	0.9481*	0.7551*	0.7497*	0.8120*	0.7493*
	Ln labo	0.3761*	0.1059**	0.3760*	0.3716*	0.3023*	0.3849*
Hedonic	Ln dens		0.7461**				
	Medi			0.1951			
	Sane				0.1197		
	Resi					-0.2904	
	Anco						-0.1881
	F	733.41	1231.61	497.69	492.70	469.25	485.39
	Adjusted R^2	0.9427	0.9765	0.9436	0.9431	0.9493	0.9423
Scale	Elasticity	1.1344	1.0540	1.1311	1.1213	1.1143	1.1342

*Independent variable significant at 99%
**Independent variable significant at 95%
***Independent variable significant at 90%
- Independent variable no significant
Source: authors' calculations

Table 9: OLS Estimates for ln Volu = f(ln reda, ln labo, hedonic variables)

Model		B 1	B 2	B 3	B 4	B 5	B 6
ln volu	constant	4.4699	-0.4579	4.4773	4.477	5.4285	3.9488
Input	ln reda	0.8016*	1.025*	0.8018*	0.8050*	0.8613*	0.8556*
	ln labo	0.2826*	-0.0336	0.2826*	0.2844*	0.1760**	0.2298*
Hedonic	ln dens		0.8737*				
	medi			-0.0117			
	sane				-0.0471		
	resi					-0.9702**	
	anco						1.1309**
	F	331.03	383.12	218.16	218.49	209.83	237.19
	Adjusted R^2	0.8812	0.928	0.8798	0.88	0.8931	0.8884
Scale	Elasticity	1.0842	0.9914	1.0844	1.0894	1.0373	1.0854

*Independent variable significant at 99%
**Independent variable significant at 95%
***Independent variable significant at 90%
- Independent variable no significant
Source: authors' calculations

Table 10: OLS Estimates for ln Cobe = f(ln reda, ln labo, hedonic variables)

Model		C 1	C 2	C 3	C 4	C 5	C 6
ln cobe	constant	5.6370	-0.0015	5.5565	5.6214	5.9704	5.6276
Input	ln reda	0.7448*	1.0004*	0.7427*	0.7373*	0.7801*	0.7458*
	ln labo	0.3620*	0.0000	0.3619*	0.3581*	0.2977*	0.3610*
Hedonic	ln dens		0.9997*				
	medi			0.1273			
	sane				0.1032		
	resi					-0.2858	
	anco						0.0202
	F	654.93	.	436.68	437.44	448.52	431.62
	Adjusted R^2	0.9363	1	0.9362	0.9364	0.9471	0.9355
Scale	Elasticity	1.1068	1.0004	1.1046	1.0954	1.0778	1.1068

*Independent variable significant at 99%
**Independent variable significant at 95%
***Independent variable significant at 90%
- Independent variable no significant
Source: authors' calculations

21. Italian Water Industry. XVII Conferenza Società Italiana di Economia Pubblica. Dipartamento di Economia Pubblica e Territoriale. Università di Pavia.
22. Frone, Simona (2008). Factors and challenges of regionalization in the water and wastewater sector. Institute of National Economy. Romanian Academy.
23. Garcia, S., M. Moreaux and A. Reynaud (2007). Measuring Economies of Vertical Integration in Network Industries: An Application to the Water Sector. International Journal of Industrial Organization 25(4), 791-820.
24. Garcia, Serge and Alban Thomas (2001). "The Structure of Municipal Water Supply Costs: Application to a Panel of French Local Communities." Journal of Productivity Analysis 16: 5-29.
25. González Gómez, Francisco and Miguel García Rubio (2008). Efficiency in the management of urban water services: What have we learned after four decades of research?. Hacienda Pública Española/ Revista de Economía Pública, 185-(2/2008). Instituto de Estudios Fiscales.
26. Hayes, K. (1987). "Cost structure of the water utility industry". Applied economics, 19(3).
27. Hempling, Scott (2009). Multi-Utility Issues at a Glance. National Regulatory Research Institute. March 1, 09-04.
28. Houtsma, John (2003). Water Supply in California: Economies of Scale, Water Charges, Efficiency, and Privatization. ERSA 2003 Congress, August.

29. Hunt, L.C. and Lynk, E.L. (1995). "Privatisation and Economic Efficiency in the UK Water Industry". Oxford Bulletin of Economics and Statistics, 57(3).
30. Iimi, Atsushi (2008). (Un)Bundling Public-Private Partnership Contracts in the Water Sector: Competition in Auctions and Economies of Scale in Operation. Policy Research Working Paper 4459. The World Bank, January.
31. Kim, H. Y. and R. M. Clark (1988). Economies of Scale and Scope in Water Supply. Regional Science and Urban Economics 18, 479-502.
32. Kim, E. and Lee, H. (1998). "Spatial Integration of Urban Water Services and Economies of Scale". Review of Urban and Regional Development Studies, 10(1).
33. McFadden, D. (1978). Cost, Revenue, and Profit Functions. Production Economics: A Dual Approach to Theory and Applications. Volume I: The Theory of Production.
34. Martins, R., F. Coelho and A. Fortunato (2006 a). Evaluating Cost Structure of Portuguese Water Utilities: Economies of Scale and Water Losses. Presented at the XVI International Reser Conference, Lisbon, September, 28-30.
35. Martins, R., F. Coelho and A. Fortunato (2006 b). "Cost Structure of the Portuguese Water Industry: a Cubic Cost Function Application", Estudos do GEMF Nº 9/2006 Grupo de Estudos Monetários e Financeiros (GEMF) - Faculdade de Economia da Universidade de Coimbra.
36. Mizutani, F. and T. Urakami (2001). "Identifying network density and scale economies for Japanese water supply organizations". Regional Science, volume 80.
37. Nauges, Céline and Caroline van den Berg (2007). How "natural" are natural monopolies in the water supply and sewerage sector? Case studies from developing and transition economies. Policy Research Working Paper 4137 4137. The World Bank, February.
38. Nauges, Céline and Caroline van den Berg (2008). "Spatial heterogeneity in the cost structure of water and sanitation services: A cross-country comparison of conditions for scale economies". 16th EAERE Conference, Gothenburg: June.
39. Nerlove, Marc (1963). Returns to Scale in Electricity Supply. En "Measurement in Economics- Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld", edited by Carl F. Christ. Stanford: Stanford University Press.
40. Oliveira, Hugo de (2008). Fronteiras Eficientes de Custos e de Producao. Workshop ARSESP sobre Temas Regulatorios. Julho.
41. Piacenza, Massimiliano and Davide Vannoni (2005). Vertical and Horizontal Economies in the Electric Utility Industry: An Integrated Approach. Higher Education Research on Mobility Regulation and the Economics of Local Services. Working Paper 1. Fondazione Collegio Carlo Alberto. Torino.
42. Piacenza Massimiliano and Davide Vannoni (2004). Choosing among alternative cost function specifications: An application to Italian multi-utilities. Economics Letters: vol 82, 415.
43. Picazo Tadeo, Andrés, Francisco Sáez Fernández and Francisco Gonzalez Gómez (2008). Assesing performance in the management of the urban water cycle. Efficiency Series Working Paper 01/2008. Departamento de Economía, Universidad de Oviedo.
44. Renzetti, S. (1999). Municipal Water Supply and Sewage Treatment: Costs, Prices, and Distortions. The Canadian Journal of Economics, Vol 32, No 3.
45. Revollo Fernández, Daniel and Giovanna Londoño (2008). Análisis de economías de escala and alcance en los servicios de acueducto and alcantarillado en Colombia. Comisión de Regulación de Agua Potable and Saneamiento Básico (CRA). Congreso de Economía, 50 Años CEDE. Universidad de Los Andes, Bogotá, octubre.
46. Saal, D. and D. Parker, D. (2005). Assessing the performance of water operations in the English and Welsh Water industry: A panel input distance function approach. Aston Business School Working Paper RP0502.
47. Sauer, J. (2005). Economies of scale and firm size optimum in rural water supply. Water Resources Research 41.
48. Shih, Jhih-Shyang, Winston Harrington, William Pizer and Kenneth Gillinham (2004). Economies of scale and technical efficiency in community water systems. Resources for the Future. Discussion Paper 04-15. February.
49. Stone and Webster Consultants (2004). Investigation into evidence for economies of scale in the water and sewerage industry in England and Wales. Prepared for OFWAT. Final Report, January.
50. Torres, M. and C. J. Morrison-Paul (2006). "Driving Forces for Consolidation or Fragmentation of the US Water Utility Industry: A Cost Function Approach with Endogenous Output". Journal of Urban Economics 59.
51. Tynan, Nicola and Bill Kingdom (2005). Optimal Size for Utilities? Public Policy For the Private Sector. Note Number 283. The World Bank, January.
52. Van den Berg, Caroline (2008). Performance assessment and benchmarking. IBNET as a tool for utility management and policy decisionmakers. Presentation. The International Benchmarking Network for Water and Sanitation Utilities. November 24.
53. Von Ginneken, Meike and Bill Kingdom (2008). Key topics in public water utility reform. Water Working Notes N° 17. The World Bank, August.
54. Von Hirschhausen, Christian, Astrid Cullmann, Matthias Walter, Rober Wand and Michael Zschille (2008). Quo vadis efficiency analysis of water distribution? A comparative literature review. Water Economics Working Paper 03. Technische Universitat Dresden. Chair in Energy Economics and Public Sector Management.

---

[i] We take sanitation and sewerage as synonymous concepts in this paper.

[ii] Physical magnitudes deserve a greater degree of accuracy in our analysis of the database. Also, the "blanks" in the database for monetary magnitudes surpassed the missing data for physical magnitudes.

[iii] Some scale and scope economy studies also use other types of functions, like the quadratic or the compound, which solve the problem under analysis.

[iv] ADERASA is the organization that groups water and sanitation regulators of the Americas. The countries included in the sample are Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru and Uruguay.

2010mss003, CCC: $10 © Inventi Journals (P) Ltd
Published on Web 19/09/2010, www.inventi.in