Utilities Policy xxx (2017) 1–10

Contents lists available at ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup

Has efficiency improved after the decentralization in the water industry in Venezuela?

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ARTICLE INFO

Article history:
Received 14 October 2016
Received in revised form
26 April 2017
Accepted 13 May 2017
Available online xxx

JEL classification:
C23
C51
G18
L11
L51
L95
Q25

Keywords:
Efficiency
Decentralization
Potable water
Sewerage
Distance function
Venezuela
Latin America

ABSTRACT

The importance of water in life and health of population, especially in developing countries, justifies the comparative study of the performance of undertakings providing potable water and waste water collection. The main objective of this research is to investigate if the decentralization process has led to an improvement of the efficiency in the water industry. Using a stochastic frontier analysis, we show that technical efficiency of Venezuelan water companies remained around 84% and that decentralized companies were more efficient than the centralized ones. The main policy recommendation is that the process of decentralization in the water services should continue.

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1. Introduction

Access to potable water and sanitation is recognized by the United Nations as an essential right for the full enjoyment of life. Each person needs around twenty to 50 L a day free of harmful contaminants, whilst wastewater collection services contribute to improving the health of a population, often preventing the spread of disease.

Companies that supply water services have to provide for all the population for which it is responsible and, furthermore, must guarantee that the supply of potable water is undertaken in accordance with the guidelines for quality required by the relevant agencies. Likewise, it is essential that effluent is collected and treated before being discharged into rivers, lakes, seas etc.

As is the case in many developing countries, in Latin America a large percentage of the population has no access to drinking water supply and wastewater collection; this problematic is even worse in rural areas. This creates significant health, social, economic and environmental problems that many agencies (United Nations, World Bank, Inter-American Development Bank, Organization of American States) have tried to mitigate through studies, counseling and investments to improve these services.

In the 70s the potable water supply service in Venezuela was characterized by low quality of water delivered, by a level of coverage about 76%, and a much lower coverage for sewerage. In

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http://dx.doi.org/10.1016/j.jup.2017.05.003
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Please cite this article in press as: Higuerey, A., et al., Has efficiency improved after the decentralization in the water industry in Venezuela?, Utilities Policy (2017), http://dx.doi.org/10.1016/j.jup.2017.05.003

1985 steps were taken to increase the level of coverage and in 1989 started a restructuring of the sector with the creation of the public company Hidroven, whose responsibility is to establish guidelines for the management, operation, maintenance and expansion of water systems and develop policies and programs on water supply, collection and treatment of wastewater. At the same time, 10 subsidiary companies of Hidroven were created, with the Venezuelan government as the main shareholder. Later, in a gradual process of transferring management of the sector to states and municipalities that lasted 20 years, nine decentralized companies were created; in this case the main shareholders are the state governments and the municipalities. Decentralization seeks to provide companies more flexibility and autonomy, both financially and in its management.

Moreover, with the aim to contribute to the improvement in the provision of services, committees called "technical water organizations" were established. They are permanent organizations that promote community participation for achieve, improve and monitor the quality in water and sanitation services and to promote a culture that values and preserve water resource and environment (Lacabana et al., 2008). In these organizations users participate in monitoring the quality, tariffs, coverage rates, investments and services.

In accordance with current regulations, the management of water supply services must be based on criteria of quality, company efficiency, reliability, equity, non-discrimination and profitability. The efficient management of companies secures return on capital and improves the price and quality of the product. However, water supply services have the characteristics of a natural monopoly. As such, the scarcity of competition provides few incentives to encourage efficient behaviour. One way of introducing competition between companies is to compare the performance between them, and determine in that way the degree of efficiency of one company's management in a fixed period in relation to the others.

Index number techniques are among the most commonly used in the measurement of the operation of companies. In Venezuela the parent company of the water sector, Hidroven, sets out indicators partial of management which provide comparative information on hydrological companies. Those indicators allow a simple way to describe the sector. However, to evaluate firms that produce more than one output using several factors, it is necessary to conduct a more comprehensive analysis in order to take into account the overall contribution of all production factors to the production.

In this context this study is of particular interest, as it applies an approach that establish comprehensive comparisons between companies; namely, it takes into consideration all the products and factors of production that effect the delivery of the service. In this way, we calculate the technical efficiency of the companies that deliver services for provision of potable water and collection of wastewater in Venezuela.

Efficiency can be assessed by employing econometric or frontier techniques. The latter can be calculated using parametric methodologies (Corton, 2003, 2011; Lin, 2005 for Peru; da Silva e Souza et al., 2007; Sabbioni, 2008 for Brazil) or non-parametric (Anwandter and Ozuna, 2002 for Mexico; Estache and Trujillo, 2003 for Argentina; Tupper and Resende, 2004 y Seroa da Motta and Moreira, 2006 for Brazil; Escalona, 2008 for Venezuela and Lin and Berg, 2008 for Peru). Some scholars have used both methodologies. These include, among others, Berg and Lin (2008) for Peru, Corton and Berg (2009) and Ferro and Romero (2011), who have compared companies in a number of Latin American countries.

The research undertaken in this study is original in various ways. Firstly, it applies a stochastic distance function for the first time to the calculation of efficiency of the water industry in Venezuela. Use of this methodology, despite its many advantages, is still not very extensive; in fact, in it has only been applied two times in this sector. Secondly, we attempt to improve the characterization of the water industry. Thus we include variables to represent the two main services in this industry (supply of potable water and collection of wastewater), as well as considering all the productive factors (many studies suffer from one of these because of lack of data). Variables have also been incorporated to take into account the operating environment in which companies work. In doing so we ensure that measures of efficiency are not affected by the omission of variables. We also inquire into the factors that influence levels of efficiency in order to determine if the decentralized process has been successful in promoting efficiency in this industry.

The paper proceeds as follows: firstly, it describes the Venezuelan water industry. Section 3 presents the methodology applied to estimate technical efficiency using a distance function. In section 4 the data used are laid out. The results derived from the empirical application are presented in section 5. Finally, section 6 shows the conclusions of our research.

2. The Venezuelan water industry

In Venezuela the governing body for potable water supply, collection and treatment of wastewater and urban drainage is a government company: Compañía Anónima Hidrológica de Venezuela (Hidroven). At present, services for potable water supply and collection of wastewater are supplied by 9 centralized companies (which are accountable to the Central Government and are coordinated by Hidroven) and 8 decentralized companies, accountable to state governments and/or municipalities. Table 1 shows the characteristics of these companies.

In line with current regulations, the use of water is under the jurisdiction of the national executive authorities (through the Ministry of popular power for the Environment), while the

Table 1
Hydrological organizations in Venezuela.

Company	Area of operation	Length (Km^2)
Centralized		
HAndes	Barinas	35,200
	Trujillo	7,400
HCapital	Distrito Capital	1,930
	Vargas	1,172
	Miranda	7,950
HCaribe	Anzoátegui	43,300
	Nueva Esparta	1,150
	Sucre	11,800
HCentro	Aragua	7,014
	Carabobo	4,650
	Cojedes	14,800
HFalcón	Falcón	24,800
HLago	Zulia	63,100
HLlanos	Apure	76,500
HPáez	Guárico	64,986
HSuroeste	Táchira	11,100
Decentralized		
CVG-GOSH	Amazonas	177,617
	Delta Amacuro	40,200
AMerida	Mérida	10,691
AMonagas	Monagas	28,900
APortuguesa	Portuguesa	15,200
AYaracuy	Yaracuy	7,100
HLara	Lara	19,800
AEjido	Mérida, municipality Campo Elías	609
HBolívar	Bolívar	240,528

Source: Hidroven. Authors.

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municipalities have competence to supply water after rendering it potable and releasing it cleanly into the environment. This regulation stipulates that services for the supply of potable water and collection of wastewater must be provided according to criteria of quality, efficiency, reliability, equity, non-discrimination and profitability. Efficiency in production secures return on capital and an improvement in the price and quality of the service, which in turn is favourable to an improvement in quality of life.

In recent years, the government has made efforts to bring potable water services to all the population. However, coverage in wastewater collection is not complete. It is reduced in less populated areas and there are widening gaps in rural areas. The situation is even worse as far as wastewater treatment is concerned, because the infrastructure is scarce and poor (Higuerey et al., 2012).

In 2001, 86% of households surveyed in Venezuela were connected to a piped-water service. However, little more than half (68%) had access to wastewater collection and only 12% received treatment of wastewater (Sandia, 2002). In 2008 coverage of potable water reached 94% and collection of wastewater accounted for a little more than 80% in 2007.

Current infrastructure for catchment and potabilization of water and for potable water conveyance allows supply to a population of nearly 30 million inhabitants (Ministerio del Ambiente, 2006). The population of Venezuela in 2011 was estimated at a level over 27 million inhabitants. Despite this apparent leeway, there have been outages. Since 2007 Venezuela has been meeting the target for the supply of potable water established by the UN as a Millennium Goal. However, the population covered with sewage service is not as extensive and in many places this service is lacking. On the other hand, unaccounted-for-water in 2003 was around 66%.

According to the Instituto Nacional de Estadística (INE), the Venezuelan pattern of consumption of water differs from that of the global trend. Whilst at the world level agricultural consumption accounts for around three quarters of water, in Venezuela the level is less than half. Domestic use of water in the country is four times the average world level, which indicates that a low value accorded to water. Underlying this behaviour is a clear lack of awareness on the part of users, and a subsidized price. Together with the above, service measurement is poor, so the actual consumption of users is not billed, leading in some cases to wastefulness (Higuerey et al., 2012).

3. Methodology

The water supply industry is characterized by being multi-output, by possessing characteristics of a natural monopoly, by being a regulated sector, and by the fact that its profitability is related to the quantity and distribution of its clients.

The majority of companies in this sector have to satisfy the requirement for a present rate and cannot choose the level of production offered (Estache and Rossi, 2002). Therefore, since output is exogenous, companies maximize benefits by reducing to a minimum the cost of production. Thus, decisions that companies can make to increase efficiency are limited to inputs that are used.

The capital factor – formed basically by the network of pipes through which water circulates, and which is distributed underground throughout the area served – has great importance to the cost structure of companies. This is a fixed factor over which companies do not have much choice. Plants for potabilization and treatment of wastewater also form a part of capital, as well as storage tanks. Other relevant inputs in the water industry are labour and electricity, over which companies have more control. The features mentioned above justify the use of an input-oriented distance function to determine the efficiency of the companies.

Distance functions (*DF*) make possible the description of technologies which use multiple inputs to produce various outputs without having to assume any given optimizing behaviour. This last feature lends this function to be appropriate for the study of regulated sectors, in which companies, rather than simply pursuing optimizing behaviour, aim to contribute to reaching objectives of public authorities. These can be social objectives, objectives pertaining to territorial cohesion, and so on. In the opinion of Pestieau and Tulkens (1994), the most appropriate criterion for comparing these types of organization is technical efficiency.

In order to determine the *DF*, it is only necessary to take into account physical data relating to the quantity of products obtained and to the factors used in the production process. This is a considerable advantage in those sectors or countries where it is difficult to make use of financial data.

A *DF* can be oriented to outputs, to inputs, or be hyperbolic. The orientation decision will depend on the characteristics of the sector.[1]

An input-oriented distance function (DF_I) is recommended principally in regulated sectors where companies have to satisfy exogenous demand, and where they only have to capacity to act on the quantity of factors used. These characteristics justify the use of DF_I to appraise efficiency in the water industry (Saal et al., 2007; Berg and Lin, 2008).

3.1. Functional form

The specification used to define DF_I is translog, which is expressed as follows:

$$\begin{aligned} lnD_{Iit} = {} & \propto_0 + \sum_{m=1}^{M} \alpha_m lny_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \alpha_{mn} lny_{mit} lny_{nit} \\ & + \sum_{k=1}^{K} \beta_k lnx_{kit} + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} lnx_{kit} lnx_{lit} \\ & + \sum_{k=1}^{K}\sum_{m=1}^{M} \delta_{km} lnx_{kit} lny_{mit} + \phi_1 T + \frac{1}{2}\phi_2 T^2 \\ & + \sum_{m=1}^{M} \eta_m lny_{mit} T + \sum_{k=1}^{K} \gamma_k lnx_{kit} T + \sum_{p=1}^{P} \xi_p z_{pit} \end{aligned} \tag{1}$$

where: y is the vector of products; x is the vector of inputs; i is the company, i-th; t is the period of time; z stands for the exogenous characteristics; and T represents a time trend; α, β, δ, ϕ, η, γ and ξ are the parameters to estimate; D_{Iit} represents the DF_I.

In order to obtain the frontier, it is vital to establish that $D_{Iit} = 1$, which supposes that the left part of the equation (1) is equal to zero. In this way, it is required that the function is symmetrical and homogeneous to degree 1 in inputs. The restrictions on homogeneity of degree 1 in inputs are expressed as:

$$\sum_{k=1}^{K}\beta_k = 1;\ \sum_{k=1}^{K}\beta_{kl} = 0\ ;\ \sum_{k=1}^{K}\delta_{km} = 0$$

The conditions for symmetry require that: $\alpha_{mn} = \alpha_{nm}$, $\beta_{kl} = \beta_{lk}$ y $\delta_{km} = \delta_{mk}$.

Now, the condition for homogeneity implies that $D_I(\omega x, y) = \omega D_I(x, y)$, for all $\omega > 0$.

Following to Lovell et al. (1994), the restrictions on homogeneity can be imposed in the equation (1) by choosing arbitrarily one of the inputs, for example, input K and establishing that. $\omega = 1/x_K$.

[1] Coelli and Perelman (1999) obtain similar results applying a *DF* to both orientations and propose using a measure of efficiency based on the geometric average of the results obtained.

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In this way, we get:

$$\ln\left(D_{lit/x_{Kit}}\right) = \propto_0 + \sum_{m=1}^{M}\alpha_m \ln y_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M}\alpha_{mn}\ln y_{mit}\ln y_{nit} + \sum_{k=1}^{K-1}\beta_k \ln x^*_{kit} + \frac{1}{2}\sum_{k=1}^{K-1}\sum_{l=1}^{K-1}\beta_{kl}\ln x^*_{kit}\ln x^*_{lit} + \sum_{k=1}^{K-1} \times \sum_{m=1}^{M}\delta_{km}\ln x^*_{kit}\ln y_{mit} + \phi_1 T + \frac{1}{2}\phi_2 T^2 + \sum_{k=1}^{K-1}\eta_k \ln x^*_{kit} T + \sum_{k=1}^{K-1}\gamma_k \ln x^*_{kit} T + \sum_{p=1}^{P}\xi_p z_{pit} \quad (2)$$

Where $x^*_{kit} = x_{kit/x_{Kit}}$. Now, if $X_{kit} = X_{Kit}$ then the ratio x^*_{kit} is equal to one, so that the logarithm will be equal to zero, disappearing all the terms in which the input *K*, appears, so that the summations of inputs goes up to *K*-1. The equation (2) can be rewritten as:

$$-\ln(x_{Kit}) = \propto_0 + \sum_{m=1}^{M}\alpha_m \ln y_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M}\alpha_{mn}\ln y_{mit}\ln y_{nit} + \sum_{k=1}^{K-1}\beta_k \ln x^*_{kit} + \frac{1}{2}\sum_{k=1}^{K-1}\sum_{l=1}^{K-1}\beta_{kl}\ln x^*_{kit}\ln x^*_{lit} + \sum_{k=1}^{K-1}\sum_{m=1}^{M}\delta_{km}\ln x^*_{kit}\ln y_{mit} + \phi_1 T + \frac{1}{2}\phi_2 T^2 + \sum_{m=1}^{M}\eta_m \ln y_{mit} T + \sum_{k=1}^{K-1}\gamma_k \ln x^*_{kit} T + \sum_{p=1}^{P}\xi_p z_{pit} - l_n(D_{lit}) \quad (3)$$

The term for distance $-\ln(D_{lit})$ can be considered as an error term that can be interpreted as a measure of inefficiency. However, the methodology applied is that of a composite error, so that the error term adopts the following form: $v_{it} - u_{it}$.

Rewriting equation (3) one gets:

$$-\ln(x_{Kit}) = \propto_0 + \sum_{m=1}^{M}\alpha_m \ln y_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M}\alpha_{mn}\ln y_{mit}\ln y_{nit} + \sum_{k=1}^{K-1}\beta_k \ln x^*_{kit} + \frac{1}{2}\sum_{k=1}^{K-1}\sum_{l=1}^{K-1}\beta_{kl}\ln x^*_{kit}\ln x^*_{lit} + \sum_{k=1}^{K-1}\sum_{m=1}^{M}\delta_{km}\ln x^*_{kit}\ln y_{mit} + \phi_1 T + \frac{1}{2}\phi_2 T^2 + \sum_{m=1}^{M}\eta_m \ln y_{mit} T + \sum_{k=1}^{K-1}\gamma_k \ln x^*_{kit} T + \sum_{p=1}^{P}\xi_p z_{pit} + v_{it} - u_{it} \quad (4)$$

where is a symmetrical error term that represents random factors that are beyond the control of the company and cannot be explained by the model; and is a non-negative error term that measures the technical inefficiency of each company u_{it} is a non-negative error term that measures the technical inefficiency of each company.

The model applied is that of Battese and Coelli (1995), which is estimated by the maximum likelihood method. The performance of the error terms is: $v_{it} \sim N(0, \sigma_v^2)$ is independent and identically distributed; y u_{it} is a random non-negative variable that assumes an independent distribution truncated at zero $N(mi, \sigma_u^2)$ where $m_{it} = z_{it}\psi$, z_{it} being the vector *px1* of the variables that can influence the efficiency of companies; y ψ being a vector *1xp* of parameters to estimate.

4. Data

The data necessary to undertake this research was facilitated by Hidroven. The sample includes all of the centralized companies and three decentralized companies. In 2008 these companies were in charge of more than 78% of the population. The period of this study encompasses from 1998 to 2008, and constructs panel data with 132 observations. Table 2 shows the average outputs and inputs by company.[2]

4.1. Products

The water industry generally provides at least two services to the population: the supply of potable water and the collection of waste water (sometimes it also undertakes the treatment of the latter). For this reason, it is characterized as a multi output industry.

The output most used in the literature is potable water: supplied (that is, the water that is distributed through the network system), invoiced (the water that is actually invoiced), and produced (the amount of potable water). According to above, our first output is billed water (*Y1*) as a proxy of the service for potable **water**. The company which bills the greatest quantity of water is HFalcon; its billing represents almost double that of the company that bills the lowest (see Table 2).

The service of wastewater collection has been defined with a wide range of variables: volume of wastewater collected, treated wastewater,[3] quality of the wastewater, connections to sanitation services per customer, contaminants removed, number of properties connected (households and non-households), population served with sanitation out of resident population, and cost of treatment plants. We have approximated the service for wastewater collection, **sewerage** (*Y2*), by the percentage of population covered by this service. The company which has the least coverage by this service is HLlanos.

4.2. Production factors

The inputs used to provide the services are: **labour** (*X1*), **electricity** (*X2*), **additional costs** (*X3*) and **capital** (*X4*). **Labour** (*X1*) is usually measured by the quantity of personnel that work in the companies, but these data were not available for all of the companies in the sample selection. Consequently, we have used the labour cost, including social security deductions, expressed in bolívares per year per inhabitant. This outlay constitutes a very influential component of the structure of total cost of the companies.

It is worth noting that recently some companies have been hiring cooperatives made up of former workers in order to carry out their own operations. This implies that the cost of personnel in companies employing these practices is less, whereas the cost of

[2] The first nine companies in the table are centralized companies; the remaining three are decentralized.

[3] The sewage treatment can be primary or secondary. Primary treatment consists of filtration, sedimentation and reduction of the biological oxygen demand of the waste water. The secondary requires chemicals to place the fluids in the channels of waters.

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Table 2
Products, input factors and environmental variables (average by company).

Company	Y1 (m^3/year)	Y2 (%)	X1 (Bs)	X2 (Bs)	X3 (Bs)	X4 (m^3/sec)	Z1 (%)	Z2 (%)	Z3 (%)
HAndes	61.07	0.79	4.71	2.22	4.69	126.24	0.01	0.54	0.17
HCapital	61.61	0.79	4.91	10.75	21.57	183.96	0.02	0.61	0.04
HCaribe	51.60	0.66	4.24	2.51	12.85	201.80	0.02	0.70	0.08
HCentro	48.46	0.82	5.60	4.55	15.50	159.50	0.01	0.62	0.13
HFalcon	81.47	0.60	14.12	5.79	20.76	218.98	0.05	0.48	0.03
HLago	55.49	0.57	3.78	3.43	12.67	154.58	0.01	0.63	0.10
HLlanos	22.94	0.54	3.72	1.71	6.47	78.18	0.00	0.63	0.55
HPáez	54.20	0.69	3.70	3.12	9.86	148.02	0.01	0.52	0.09
HSuroeste	57.63	0.66	5.35	0.60	8.76	138.36	0.03	0.57	0.05
AMerida	53.55	0.56	6.55	0.44	7.66	177.99	0.04	0.63	0.02
APortuguesa	54.76	0.57	2.39	2.31	4.88	74.11	0.02	0.49	0.45
AYaracuy	44.35	0.64	3.75	2.35	4.16	152.06	0.00	0.53	0.15

Bs: Bolívares.
Source: Hidroven, National Institute of Statistic of Venezuela. Authors.

subcontracting personnel is increased by various additional costs.

The water industry requires energy in order to pump potable water and waste water into systems for water collection, treatment and final distribution. **Electricity** (*X2*) has been included as a second factor, which has been measured in the literature in different ways, by recommending using actual consumption measured in kilowatts. Since Hidroven does not provide this information, we have used the outlay for electrical energy, measured in bolívares per year per inhabitant.

Also included as a production factor were **other costs** (*X3*), determined by the difference between the total of operating costs and labour costs and electricity. This is expressed in bolívares per year per inhabitant. This variable captures all of the other inputs in the production process: chemicals, materials and supplies, other operating costs and industry maintenance.

Capital is generally the factor that has the most impact on the cost structure. Following to Coelli and Walding (2005) the capacity for the water purification plants of each company, measured in m^3/second, has been used to give an approximate value for the **capital** factor (*X4*). In general, the greater the size of a population supplied by a company, the greater its capacity to cover the needs of the population must be. In Venezuela, the capacity installed for potabilization enables the provision of this service to 30 million inhabitants.[4]

HFalcon is the company which has the greatest personnel outlay per inhabitant, and the greatest capacity for potabilization per inhabitant. HCapital spends the most on electricity and other costs, per inhabitant. The descriptive statistics for all of the variables used in the determination of efficiency in the water industry are presented in Table 3.

4.3. Environmental variables

In many cases, companies are faced with factors that are not inputs, but which affect the activity or the quality of the service they provide and, as such, its efficiency. These are termed environmental or exogenous variables. Since these variables play a significant role in obtaining the output, they should be included in the model specification. Otherwise this could lead to incorrect conclusions regarding the efficiency of each company.

In most countries, companies measure the water consumed by customers and charge rates according to real consumption. However, in developing countries, a significant number of users of potable water services do not have counters, and sometimes installed meters are not read. In these countries not every connection has a counter. There are buildings connected to water distribution networks that do not have a meter to measure the amount of water consumed. Although some Latin American countries have established metering systems, they are not used frequently. So a significant amount of water supplied has not been billed, causing financial damage to the company. In Venezuela the number of meters installed is low, so that, in most cases, water that is billed is not measured and a fixed quantity is charged regardless of the amount of water consumed. **Connections** is a variable which reflects the number of connections that are measured (*Z1*). This is determined by the total number of connections with a functioning meter divided by the total number of connections per inhabitant.

In developed countries lost water is an indicator of the technical quality of a service (Coelli et al., 2003). Large losses of water may indicate an antiquated network, which incurs high maintenance costs (Bhattacharyya et al., 1995). This is the case in many developing countries where, the infrastructure is outdated, resulting in large amount of water lost in the distribution system. Water losses are also a big problem for Venezuelan companies, reaching up to 60% of water supplied. In order to reflect the impact of this problem the variable **loss** (*Z2*) is incorporated. This is determined as the ratio between water supplied and water billed.

The water industry is able to obtain its primary resource from groundwater or surface water. The first of these is extracted from aquifers that are under the earth's surface. Wells are constructed to obtain it. Depending on the porosity of the earth, these waters are likely to have a high grade of purity. Surface water sources are rivers, lakes, wells, springs and seas (salt water). The degree of purity of raw water [5] will depend on the location of the source and its surroundings, and affects the potabilization treatment of the water. Nearly 90% of water that is processed in Venezuela comes from surface water. To capture this characteristic, the variable **groundwater** (*Z3*) is incorporated, dividing the water extracted from underground sources by the total amount of water extracted.

Wastewater must be treated before being discharged. Treatment of wastewater is a strategy that multilateral institutions have wanted to implement in developing countries, since a large amount of waste water is disposed of without proper treatment causing disease and certain environmental problems. In Venezuela the incidence of treatment is low. Companies that apply such treatment use technology that requires more inputs. To reflect this fact, a

[4] According to the 2011 census, the population of Venezuela is 27,150,095 inhabitants (http://www.ine.gov.ve).

[5] Raw water is that which has received no kind of treatment. Its degree of purity is the same as its original source.

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Table 3
Descriptive statistics of variables.

Variable	Definition[a]		Average	Minimum	Maximum
Products	Water invoiced (m^3 per year)	Y1	53.93	14.27	85.05
	Population with sewer (inhabitant)	Y2	0.656	0.344	0.928
Production factors	Labour (Bolívares)	X1	5.236	0.781	38.916
	Energy (Bolívares)	X2	3.316	0.035	14.645
	Other costs (Bolívares)	X3	10.819	0.500	52.028
	Treatment capacity (m^3 per year)	X4	151.15	63.36	239.30
Environmental variables	Metered connections (%)	Z1	0.02	0.00	0.07
	Loss of water (%)	Z2	0.58	0.12	0.90
	Groundwater (%)	Z3	0.16	0.02	0.55
	Wastewater treatment (dummy)	D1		7	11
	Region			**N° companies (%)**	
	Andes (dummy)	R1		3	(25)
	Capital (dummy)	R2		1	(8.33)
	Central (dummy)	R3		1	(8.33)
	West Central (dummy)	R4		3	(25)
	Los Llanos (dummy)	R5		2	(16.67)
	Northeast (dummy)	R6		1	(8.33)
	Zuliana (dummy)	R7		1	(8.33)
Efficiency factors	Administration (dummy)	D2		3	(25)
				N° years (%)	
	Technical water organizations (years)	D3		3	(27.27)

[a] All variables were relativized per capita.
Source: Hidroven, National Institute of Statistic of Venezuela. Authors.

dummy variable, **treatment** (*D1*), is used. This takes the value 1 if the company provides the service and 0 if it does not.

Venezuela is divided into seven regions: Andes, Capital, Central, Centro Occidental, Los Llanos, Nororiental and Zulia. In view of the heterogeneous features that exist in these regions, 7 dummy variables have been created to reflect the fixed effects of these differences.

4.4. Efficiency factors

Usually, not all companies have the same level of efficiency. Therefore, worth investigating the cause of these differences. For this purpose, we have considered the variables explained in detail below.

Companies in Venezuela that provide services for supply of potable water and collection of wastewater are classified, depending on their administrative autonomy, as either centralized or decentralized. In the former, decisions are taken by Hidroven, which provides companies resources for investments and to cover deficits and employ workers and public functionaries. Decentralized companies are financed with resources that derive from their operations. Regional and municipal governments participate in the decision-making process of their operations, and their employees are regulated according to a flexible and particular law. Unlike centralized companies, decentralized companies have no direct relationship with the national authorities.

A dummy variable is incorporated to determine whether the form of organization impacts on the efficiency of companies. This variable is denoted **administration** (*D2*) and takes the value 1 if the company is decentralized and 0 if it is centralized.

In 2003 Technical Water Organizations (TWO) were initiated in Venezuela. These aim to promote the continuing participation of the community to obtain, improve, and overlook the potable water and wastewater services in their areas, and to promote a culture that values and takes care of this resource and the environment. In 2005 more than 2000 TWO were established. To reflect the influence of these organizations on the efficiency of companies, a dummy variable has been created (*D3*) which takes the value 0 until the year 2005, and the value 1 from 2006, the year in which the establishment of this type of organization increased rapidly.

5. Empirical results

5.1. Output and input variables

The results of the estimate for the equation (4) are shown below. To facilitate the interpretation of the parameters of the translog function, the data have been normalized by dividing every input and every output by its geometric mean.

The parameters calculated applying the DF_I must be consistent with the properties of this model: non-increasing in outputs and non-decreasing in inputs. Consequently, the sign for the first-order parameters corresponding to outputs must be negative, and that of inputs positive. An increase in the level of any of the outputs generates a reduction in the distance of the respective company studied with respect to the frontier, and a diminution in inputs will lead to a reduction in the distance of the company being analyzed.

The estimate results are presented in Table 4. The parametric symbols for the first order coefficients fulfil the required properties and the majority are sufficiently significant. Capital (*X4*) is the productive factor that has the greatest incidence when determining the variations of distance. Next in importance are labour (*X1*) and electricity (*X2*), respectively. The variable other costs (*X3*) has a low coefficient and is of little significance.

The DF_I is non-decreasing in *x*, non-increasing in *y*, homogeneous of degree 1 in *x*, concave in *x*. The estimated DF_I satisfies these requirements. The sign for outputs is negative in 86.36% of *Y1* and in 75.00% of *Y2*, and the elasticity is positive for the inputs: *X1* and *X4* at 100%, *X2* at 92.42% and *X3* at 68.94% (see Table 5).

5.2. Environmental variables

Four variables are included in the model in order to capture the technological and environmental differences of companies. The

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Table 4
Estimated parameters.

Variable	Par.	Coef.	T-ratio
Constant	α_0	0.476	10.089
Inputs			
ln X1	β_1	0.156	
ln X2	β_2	0.085	2.864
ln X3	β_3	0.048	1.512
lnX4	β_4	0.711	19.324
ln X1. ln X1	β_{11}	−0.071	
ln X2. ln X2	β_{22}	0.006	0.192
ln X3. ln X3	β_{33}	−0.089	−1.730
ln X4. ln X4	β_{44}	−0.038	−0.297
ln X1. ln X2	β_{12}	0.031	
ln X1. ln X3	β_{13}	−0.107	
ln X1. ln X4	β_{14}	0.004	0.489
ln X2. ln X3	β_{23}	0.063	2.051
ln X2. ln X4	β_{24}	−0.100	−2.184
ln X3. ln X4	β_{34}	0.133	1.992
Outputs			
ln Y1	α_1	−0.341	−5.153
ln Y2	α_2	−0.237	−3.525
ln Y1. ln Y1	α_{11}	−0.639	−5.859
ln Y2. ln Y2	α_{22}	−1.023	−1.065
ln Y1. ln Y2	α_{12}	1.390	7.684
ln Y1. ln X1	δ_{11}	0.237	
ln Y1. ln X2	δ_{12}	−0.013	−0.317
ln Y1. ln X3	δ_{13}	−0.057	−0.584
ln Y1. lnX4	δ_{14}	−0.167	−1.444
ln Y2. ln X1	δ_{21}	0.703	
ln Y2. ln X2	δ_{22}	−0.103	−1.178
ln Y2. ln X3	δ_{23}	0.011	0.066
ln Y2. lnX4	δ_{24}	−0.610	−2.352
Time			
T	ϕ_1	0.031	6.014
T^2	ϕ_2	0.007	2.833
ln X2.t	γ_2	0.013	2.665
ln X3.t	γ_3	0.002	0.328
ln X4.t	γ_4	0.025	2.067
ln Y1.t	η_1	−0.018	−1.721
ln Y2.t	η_2	−0.011	−0.306
Environmental			
Z1	ξ_1	0.057	5.927
Z2	ξ_2	−0.108	−2.257
Z3	ξ_3	0.238	9.193
D1		−0.209	−7.851
R1	ξ_4	−0.007	−0.133
R2	ξ_5	−0.249	−3.399
R3	ξ_6	−0.202	−3.977
R4	ξ_7	−0.201	−7.174
R6	ξ_8	−0.246	−7.663
R7	ξ_9	−0.102	−3.287
Inefficiency			
Constant	Ψ_0	0.226	8.064
D2	Ψ_1	−0.475	−7.189
D3	Ψ_3	0.043	1.598
Sigma-squared		0.005	21.544
Gamma		0.879	6.094
Log likelihood function			185.238
LR test of the one-sided error			4.390
Average efficiency			0.838

The model is estimated by maximum likelihood, which is used for the parameterization suggested by Battese and Corra (1977), estimating $\sigma^2 = \sigma_v^2 + \sigma_u^2 \quad y\ \gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$.

results were as expected and they are consistent with other empirical works.

The connections measured have an ambiguous effect on inputs (Saal et al., 2007). On the one hand, a greater measurement of water consumed would lead to a decrease in the demand for water, when having to pay for real consumption. Because of this, a reduction in input requirements would be expected. On the other hand, the installation of meters requires investment of capital, and the reading of meters entails an increase in operating costs. In the estimated model, the coefficient of the variable *Z1* is low, and presents a positive and highly significant sign. This indicates that the little measuring that has been carried out by companies in Venezuela has led to an increase in the demand for water.

Unaccounted for water has a strong impact on the decrease in the frontier, as the sign for the variable *Z2* indicates. This variable controls the differences caused by loss of water in the system of water distribution and the requirements for inputs. It is possible to infer that the water losses have required more inputs. This result is consistent with Escalona (2008), who found that the loss of water had a negative effect on the provision of the service and on the costs of the water companies in Venezuela, thus affecting the efficiency of companies.

The companies that employ groundwater use fewer inputs, as one can see by means of the sign for the variable *Z3*. This could be due to the fact that this water is purer and requires less treatment. It could be argued that companies that use a greater proportion of underground water have advantages over other operators.

Finally, as was to be expected, companies that treat wastewater in Venezuela use a higher quantity of production factors than those which do not. It is as much the sign for the *dummy D1* as the high level of significance that demonstrate this situation.

5.3. Efficiency factors

Formerly the water service in Venezuela was supplied by the Instituto Nacional de Obras Sanitarias (INOS). Later, INOS was turned into regional companies dependent on central authority, with the possibility of being converted into decentralized companies for a smaller region or for municipalities. At present, 9 centralized and 8 decentralized companies coexist. As explained before, the decentralized water firms are more flexible than the centralized ones in issues as finance, management and in contracting labour input. Those characteristics drive them to a more efficient management. Our model confirms that the decentralized companies are more efficient than the centralized ones (see Table 4).

The variable that captures the effect of incorporation of the Technical Water Organizations (TWO), or technical water committees, into the management of operating companies is of limited value and is not significant. Therefore, the TWO have not impacted on the efficiency of operating companies. It was hoped that these TWO, which help to resolve problems in services to the community, would have had a positive effect on the efficiency of companies. This result must be taken with caution, as it can be conditioned by the way of measuring this variable. Perhaps if more information was available about the TWO, it could be tested if they have had a positive impact on efficiency.

5.4. Technological change

In equation (4), ϕ_1 is interpreted as the rate of technological change reached by a hypothetical company that represents the average for the sample companies, and ϕ_2 as the estimated annual rate of technological change that the hypothetical company experiences. ϕ_1 is statistically significant and suggests that, on average, the sample has an annual rate of technological change of 3.1%.

As the data have been standardized with the sample average, the technological change that the hypothetical company would achieve is calculated as $\phi_1 + \phi_2\,(t + 0.5)$ (Saal et al., 2007).

The estimated parameterϕ_2 is statistically significant and suggests that the technological change grew from -0.05% in 1998 to 6.95% in 2008. The technological changes oriented to the inputs and outputs measured by the parametersγ_k and η_m, demonstrate the nature of technological change in the industry, and suggest that

Please cite this article in press as: Higuerey, A., et al., Has efficiency improved after the decentralization in the water industry in Venezuela?, Utilities Policy (2017), http://dx.doi.org/10.1016/j.jup.2017.05.003

Table 5
Properties of the distance function.

Elasticity	Average	Standard deviation	Minimum	Maximum	% Positive	% Negative
Y1	−0.341	0.284	−1.040	0.490	13.64	86.36
Y2	−0.237	0.551	−1.534	1.147	25.00	75.00
X1	0.156	0.048	0.026	0.359	100.00	0.00
X2	0.085	0.055	−0.112	0.218	92.42	7.58
X3	0.048	0.075	−0.140	0.285	68.94	31.06
X4	0.711	0.130	0.269	1.033	100.00	0.00
Scale elasticity	−0.577	0.429	−1.699	0.602	10.61	89.39

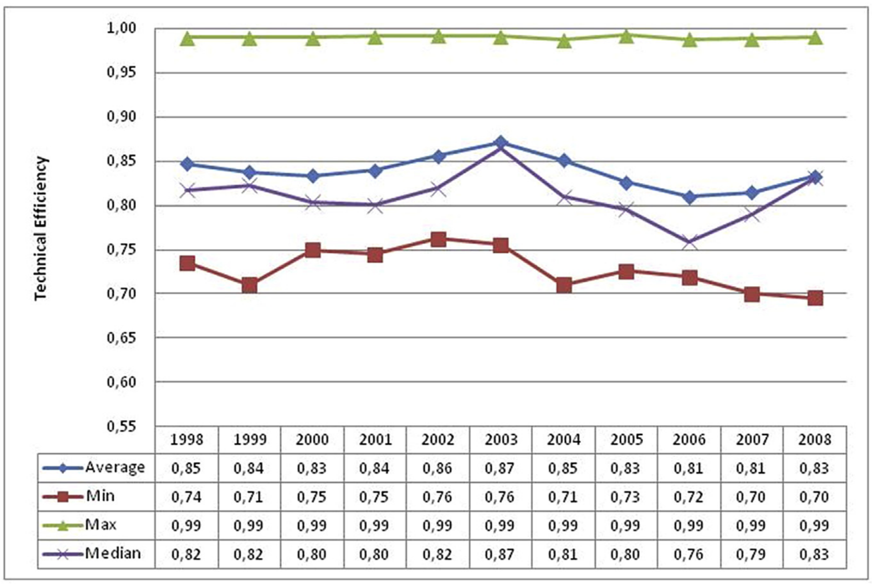

Fig. 1. Average technical efficiency, 1998–2008.

increases in outputs and inputs have contributed positively to technological change.

5.5. Technical efficiency

The average efficiency of Venezuelan companies that provide services for the supply of potable water and collection of wastewater is significantly high and has had the following performance (see Fig. 1). After a slight decrease, a period of increase was initiated until 2003, only to decrease again, reaching its lowest point of efficiency in 2006. After a recovery, figures in 2008 reached a level slightly inferior to those for 1998.

This performance for average efficiency is strongly influenced by the development of minimum efficiency. Whilst maximum efficiency has been maintained roughly at a constant level, the minimum shows a variation of approximately 5 points, with a downward tendency in recent years, moving further away from average efficiency.

In Fig. 2 one can see that decentralized companies (AMerida, APortuguesa and AYaracuy) are more efficient than their centralized counterparts (the averages in this period being 0.79% for centralized companies and 0.98% for decentralized companies). For a significant proportion of the centralized companies, efficiency was reduced in the years analyzed. The worst situation was recorded at the companies HLago and HLlanos which, starting from a high point dropped to the lower positions (see Fig. 3). The companies HCapital and HCaribe improved their efficiency to the extent of being among the top ranked centralized companies.

Fig. 4 shows the average technical efficiency based on the size of the company, defined by the population served. The following categories have been drawn up: size 1 for companies that serve more than a million inhabitants; size 2 for companies that serve more than 500,000 and less than a million; and size 3, which encompasses those companies which serve 100,000 to 500,000 inhabitants.

Fig. 2. Technical efficiency by type of company.

The results show that the companies which serve a population between 500,000 and 1,000,000 inhabitants (size 2) are the most efficient. All of the decentralized companies are in this population category. On the other hand, the ones which serve a greater population (size 1) are those with the lowest efficiency and the only ones to have improved over the last year.

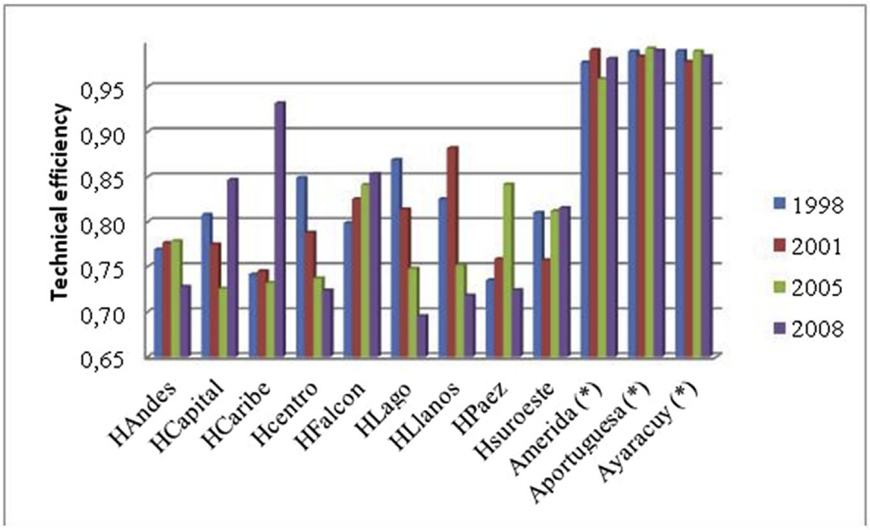

Fig. 3. Technical efficiency by company, 1998, 2001, 2005 and 2008.

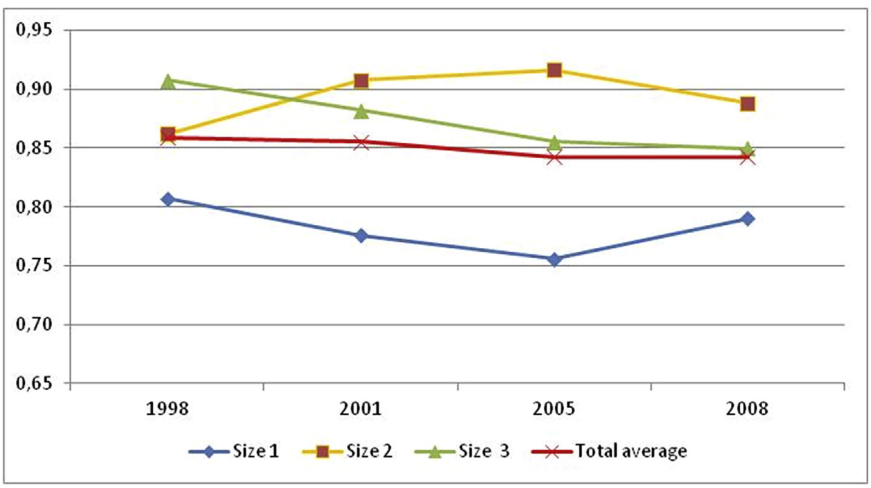

Fig. 4. Average technical efficiency by size, 1998, 2001, 2005 and 2008.

6. Conclusions

This study has quantified the technical efficiency for the services of potable water supply and wastewater collection in Venezuela by using a distance function oriented to inputs. For this, data from twelve Venezuelan water companies was employed, which were responsible for more than three quarters of the population during the 1998–2008 period.

Overall, we can state that efficiency of Venezuelan water companies has remained at around 84% in the period considered. In any case, the aim of this work not only was to measure the efficiency but to verify if the decentralization of the management of the water service allowed to improve the efficiency in the service.

We found that decentralized companies have been much more efficient than centralized ones. Their performance has been such that the global level of efficiency in this sector is high. In addition, it is possible to assert that the decentralization generates a positive effect in the technical efficiency. Decentralized firms do not receive financing from the central government, but rather are self-financed, so they have tried to be efficient and to gradually meet the needs of the population. In fact, decentralized firms are around 20 percentage points more efficient than centralized ones. This result suggests that it would be desirable to establish a decentralization process which allows to the 10 firms that remain operating centrally to be more efficient in the water services.

Despite the improvements with regard to increase the population with access to potable water and with access to wastewater collection, a question remains in Venezuela around the issue of potable water that is supplied but is not billed in its entirety. Metered connections have shown a positive impact on efficiency frontier. So it is necessary to increase the number of micrometers, as well as the reading of these, so that companies can bill the real consumption of users. This would enable the generation of additional income to cover the real costs of the operators and, at the same time, would help to diminish the waste or misuse of water by some customers.

Another fact that explains that the water supplied is not invoiced is the losses of water in the system. The high level of water losses affects the management of companies in this country. These features mean that companies must use a greater quantity of inputs in the provision of their services. The main reasons of water losses in the distribution process water in Venezuela are the lack of

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maintenance of the networks and illegal connections by users. It is necessary to design a system of incentives that encourage companies to verify water losses and to make investments in network maintenance. This would contribute to better utilization of inputs and, therefore, an improvement in efficiency.

Technical Water Organizations (TWO) have done a great deal in facilitating and controlling the relationship between companies and communities, but we could not prove their contribution to improving the efficiency of the operating companies. With regard to this question, having better data on the number of TWO and functions that have developed in each community would allow a better assessment of the impact of TWO on the efficiency of water companies in Venezuela. This is an interesting question, which it is characteristic of the water industry in Venezuela, to be analyzed in futures researches.

Despite the current law stipulating that one regulatory agency must be created, Venezuela does not have a specific regulatory body that supervises the conditions of service provision, possibly because of the public character of the provider companies of this service. This regulatory agency has important work to undertake. Among others, gather the necessary information to enhance the estimations of efficiency of firms in the Venezuelan water industry. Increase the availability of data to incorporate variables that were not available for this research, such as pipework, variables that reflect water quality and information about TWO would allow to improve the results of this research.

Acknowledgments

This research was financed by the Government of the Canary Islands through the project 'Efficiency of water companies in the Canary Islands', and through the Agencia Canaria de Investigación, Innovación y Sociedad de la Información (ACIISI), reference number PROID20100256. The authors would like to thank the Compañía Anónima Hidrológicas de Venezuela (HIDROVEN) for the data provided to undertake this work.

References

Anwandter, L., Ozuna, T., 2002. Can public sector reforms improve the efficiency of public water utilities? Environ. Dev. Econ. 7 (4), 687–700.

Battese, G., Coelli, T., 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empir. Econ. 20, 325–332.

Battese, G.E., Corra, G.S., 1977. Estimation of a production frontier model: with application to the pastoral zone of Eastern Australia. Aust. J. Agric. Econ. 21, 169–179.

Berg, S., Lin, C., 2008. Consistency in performance rankings: the Peru water sector. J. Appl. Econ. 40 (6), 793–805.

Bhattacharyya, A., Harris, T., Narayanan, R., Raffiee, K., 1995. Specification and estimation of the effect of ownership on the economic efficiency of the water utilities. Reg. Sci. Urban Econ. 25 (6), 759–784.

Coelli, T., Perelman, S., 1999. A comparison of parametric and non-parametric distance functions: with application to European railways. Eur. J. Oper. Res. 117 (2), 326–339.

Coelli, T., Walding, S., 2005. Performance Measurement in the Australian Water Supply Industry. CEPA Working Paper Series, 01/2005.

Coelli, T., Estache, A., Perelman, S., Trujillo, L., 2003. Una introducción a las medidas de eficiencia. In: Grupo, Alfaomega (Ed.), Para reguladores de servicios públicos y de transporte (Colombia).

Corton, M.L., 2003. Benchmarking in the Latin American water sector: the case of Peru. Util. Policy 11 (3), 133–142.

Corton, M.L., 2011. Sector fragmentation and aggregation of service provision in the water industry. J. Prod. Anal. 35, 159–169.

Corton, L., Berg, S., 2009. Benchmarking Central America water utilities. Util. Policy 17 (3–4), 267–275.

da Silva e Souza, G., Coelho de Faria, R., Moreira, T., 2007. Estimating the relative efficiency of Brazilian publicly and privately owned water utilities: a stochastic cost frontier approach. J. Am. Water Resour. Assoc. 43 (5), 1237–1244.

Escalona, L., 2008. Water Market in Venezuela: Analysis of Global Economic and Technical Efficiency of the Venezuelan Water Companies. PhD Thesis Zaragoza University, Spain.

Estache, A., Rossi, M., 2002. How different is the efficiency of public and private water companies in Asia. World Bank. Econ. Rev. 16 (1), 139–148.

Estache, A., Trujillo, L., 2003. Efficiency effects of privatization in Argentina's water and sanitation services. Water Policy 5 (4), 369–380.

Ferro, G., Romero, C., 2011. Setting performance standards for regulation of water services: benchmarking Latin American utilities. Water Policy 13, 607–623.

Higuerey, A., González, M.M., Trujillo, L., 2012. Current situation of water supply services in Venezuela. Rev. Venez. Econ. Soc. 12 (24), 9–36.

Lacabana, M., Cariola, C., La Rosa, I., Maldonado, A., Villasmil, M., Vielma, L., 2008. Las mesas técnicas de agua en el contexto de los cambios institucionales, la democracia participativa y la participación popular en Venezuela. Informe final del Proyecto: "Mesas Técnicas de Agua, proyectos comunitarios y análisis de los procesos de participación" Contrato Nº GPFFC-02–2007 (Cendes-Hidroven) (Versión Preliminar). Caracas. Disponible en: http://www.hidroven.gov.ve/publicaciones/912560_MTA%20AutoresVarios.pdf. (accessed 11.09.20).

Lin, C., 2005. Service quality and prospects for benchmarking: evidence from the Peru water sectors. Util. Policy 13 (3), 230–239.

Lin, C., Berg, S., 2008. Incorporating service quality into yardstick regulation: an application to the Peru water sector. Rev. Ind. Organ. 32, 53–75.

Lovell, C., Richardson, S., Travers, P., Wood, L., 1994. Resources and functionings: a new view of inequality in Australia. In: EnEichhorn, W. (Ed.), Models and Measurement of Welfare and Inequality. Springer-Verlag, Berlin.

Ministerio del Ambiente, 2006. Recursos hídricos de Venezuela. Fondo editorial Fundambiente, Caracas.

Pestieau, P., Tulkens, H., 1994. Assessing the Performance of Public Sector Activities: Some Recent Evidence from the Productive Efficiency Viewpoint. Discussion paper Nº 9060 (CORE), Universite Catholique de Louvain.

Saal, D.S., Parker, D., Weyman-Jones, T., 2007. Determining the contribution of technical change, efficiency change an scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985-2000. J. Prod. Anal. 28 (1), 127–139.

Sabbioni, G., 2008. Efficiency in the Brazilian sanitation sector. Util. Policy 16, 11–20.

Sandia, M., 2002. Ley orgánica para la prestación de los servicios de agua potable y de saneamiento. Estudio sobre el régimen jurídico de la prestación de los servicios de agua potable y saneamiento (Una posibilidad cierta para disponer de servicios eficientes). Editorial Jurídica venezolana, Caracas.

Seroa da Motta, R., Moreira, A., 2006. Efficiency and regulation in the sanitation sector in Brazil. Util. Policy 14, 185–195.

Tupper, H.C., Resende, M., 2004. Efficiency and regulatory issues in the Brazilian water and sewage sector: an empirical study. Util. Policy 12 (1), 29–40.